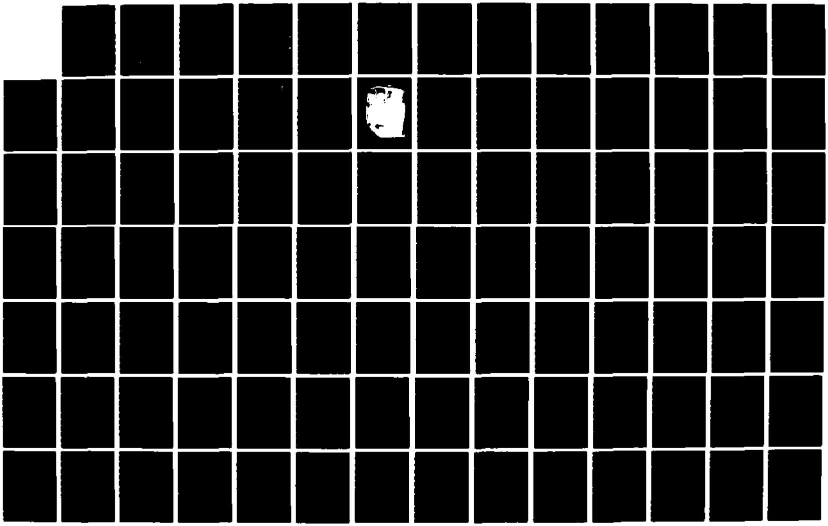
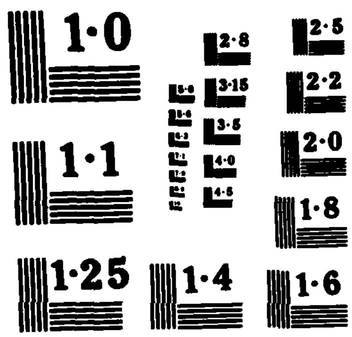
AD-A157 724 MEASUREMENT OF RF (RADIO FREQUENCY) FIELDS ASSOCIATED WITH ISM (INDUSTRIA..(U) OHIO UNIV ATHENS AVIONICS ENGINEERING CENTER J D NICKUM ET AL. MAY 85 1/2

UNCLASSIFIED OU/AEC/EER-67-1 DOT/FAA/ES-84/2 F/G 20/14 NL





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(2)

DOT/FAA/ES-84/2

Systems Engineering Service
Washington, D.C. 20591

Measurement of RF Fields Associated With ISM Equipment as it Relates to Aeronautical Services

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May 1985

Final Report

U.S. Department of Transportation
Federal Aviation Administration

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/ES-84/2	AD-A157 724	

4. Title and Subtitle
Measurement of RF Fields Associated with ISM Equipment as it Relates to Aeronautical Services

5. Report Date

6. Performing Organization Code
May 1985

7. Author(s)
James D. Nickum, P.E., William Drury

8. Performing Organization Report No.
OU/AEC/EER 67-1

9. Performing Organization Name and Address
Avionics Engineering Center
Department of Electrical & Computer Engineering
Athens, Ohio 45701-2979

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DTFA01-83-C-10007

12. Sponsoring Agency Name and Address
Federal Aviation Administration
Spectrum Engineering Division, AES-500
Washington, D.C. 20590

13. Type of Report and Period Covered
FINAL REPORT

14. Sponsoring Agency Code
AES-500

15. Supplementary Notes

16. Abstract

Described are the RF field measurements of four Industrial, Scientific and Medical devices to characterize the fundamental and 4th harmonic radiation from these devices according to FCC Part 18 and CISPR Publication 11 and 11A. The effects of the 4th harmonic radiation is considered with respect to ILS localizer receiver susceptability. The testing was performed at an open field test site with measurements made on the ground and at elevation angles from 45 to 75 degrees.
Additionally, an aircraft equipped with calibrated antennas was flown over the ISM device to determine the RF fields radiated overhead at the 4th harmonic of the fundamental operating frequency. The four ISM devices consisted of one with 25 kW power output, two with 2 kW power output, and one at 3 kW power output.
Results indicate that RF fields (at ILS localizer frequencies) of 20 to 40 dB above FCC limits can exist as a result of ISM equipment 4th harmonic emissions in the vicinity of ISM equipment. Co-channel emissions from ISM devices on localizer frequencies can produce CDI deviations in excess of 5 ua at the missed approach point for certain locations of ISM equipment.

17. Key Words	18. Distribution Statement
Industrial, Scientific and Medical, ISM Airborne measurements, RF Field Measurements, ILS Localizer.	This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	176	

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English/Metric Conversion Factors

Length

From \ To	Cm	m	Km	in	ft	s mi	nmi
Cm	1	0.01	1×10^{-5}	0.3937	0.0328	6.21×10^{-6}	5.39×10^{-6}
m	100	1	0.001	39.37	3.281	0.0006	0.0005
Km	100,000	1000	1	39370	3281	0.6214	0.5395
in	2.540	0.0254	2.54×10^{-5}	1	0.0833	1.58×10^{-5}	1.37×10^{-5}
ft	30.48	0.3048	3.05×10^{-4}	12	1	1.89×10^{-4}	1.64×10^{-4}
S mi	160,900	1609	1.609	63360	5280	1	0.8688
nmi	185,200	1852	1.852	72930	6076	1.151	1

Area

From \ To	Cm^2	m^2	Km^2	in^2	ft^2	S mi^2	nmi^2
Cm^2	1	0.0001	1×10^{-10}	0.1550	0.0011	3.86×10^{-11}	5.11×10^{-11}
m^2	10,000	1	1×10^{-6}	1550	10.76	3.86×10^{-7}	5.11×10^{-7}
Km^2	1×10^{10}	1×10^{6}	1	1.55×10^{9}	1.08×10^{7}	0.3861	0.2914
in^2	6.452	0.0006	6.45×10^{-10}	1	0.0069	2.49×10^{-10}	1.88×10^{-10}
ft^2	929.0	0.0929	9.29×10^{-8}	144	1	3.59×10^{-8}	2.71×10^{-8}
S mi^2	2.59×10^{10}	2.59×10^{6}	2.590	4.01×10^{9}	2.79×10^{7}	1	0.7548
nmi^2	3.43×10^{10}	3.43×10^{6}	3.432	5.31×10^{9}	3.70×10^{7}	1.325	1

Volume

From \ To	Cm^3	Liter	m^3	in^3	ft^3	yd^3	fl oz	fl pt	fl qt	gal
Cm^3	1	0.001	1×10^{-6}	0.0610	3.53×10^{-5}	1.31×10^{-6}	0.0338	0.0021	0.0010	0.0002
liter	1000	1	0.001	61.02	0.0353	0.0013	33.81	2.113	1.057	0.2642
m^2	1×10^{6}	1000	1	61,000	35.31	1.308	33,800	2113	1057	264.2
in^3	16.39	0.0163	1.64×10^{-5}	1	0.0006	2.14×10^{-5}	0.5541	0.0346	2113	0.0043
ft^3	28,300	28.32	0.0283	1728	1	0.0370	957.5	59.84	0.0173	7.481
yd^3	765,000	764.5	0.7646	46700	27	1	25900	1616	807.9	202.0
fl oz	29.57	0.2957	2.96×10^{-5}	1.805	0.0010	3.87×10^{-5}	1	0.0625	0.0312	0.0078
fl pt	473.2	0.4732	0.0005	28.88	0.0167	0.0006	16	1	0.5000	0.1250
fl qt	946.3	0.9463	0.0009	57.75	0.0334	0.0012	32	2	1	0.2500
gal	3785	3.785	0.0038	231.0	0.1337	0.0050	128	8	4	1

Mass

From \ To	g	Kg	oz	lb	ton
g	1	0.001	0.0353	0.0022	1.10×10^{-6}
Kg	1000	1	35.27	2.205	0.0011
oz	28.35	0.0283	1	0.0625	3.12×10^{-5}
lb	453.6	0.4536	16	1	0.0005
ton	907,000	907.2	32,000	2000	1

Temperature

$^{\circ}C = 5/9\,(^{\circ}F - 32)$

$^{\circ}F = 9/5\,(^{\circ}C) + 32$

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I. INTRODUCTION

This report details the procedures, measurements, analysis, and recommendations of a measurements program which was designed to determine the radio frequency (RF) fields of the fundamental and 4th harmonics of devices classed as industrial, scientific, and medical. This equipment is licensed to operate from 26.96 - 27.28 MHz; and the emission of harmonics is regulated by the United States under the Federal Communications Commission (FCC) Part 18 of the Rules and Regulations.

The 4th harmonics of this equipment fall within the frequency allocation of the aeronautical instrument landing system (ILS) band. Therefore, the FAA is interested in what real RF fields exist over and around any industrial, scientific and medical (ISM) device and what RF fields are capable of causing serious interference to aeronautical users. The FAA's interest is in obtaining actual measured results in order to substantiate requests made to the FCC to increase or decrease emissions standards for certification of ISM devices. This report presents data comparing the RF fields measured, based on FCC and Comite International Special Des Perturbations Radioelectriques (CISPR) procedures, to the RF fields measured by an aircraft flying over the ISM device at various elevation angles.

Four ISM devices were tested for this report. One device with an RF power output of 25 kW, two devices at 2 kW, and one device at 3 kW were tested at the Elite Electronic Engineering open field test site in Waterman, Illinois. The class of ISM devices tested was dielectric sealers used to seal vinyl and other similar materials. The load used for these tests was silicone, in order to obtain a longer dwell time for ease in making the RF measurements.

The equipment selected for these tests was chosen as a representative range of devices currently used in the industry with power outputs in the range of 2 - 25 kW. Additionally, the ISM devices were new equipment.

Tests were performed in three categories. The first was that RF emission tests were to be made according to FCC and CISPR procedures as if the equipment were to be certified for use. Second, a set of tests was made such that an antenna could be placed at various elevation angles to measure any radiation occurring at vertical angles. Third, a set of measurements was made using an aircraft equipped with calibrated antennas and flown over the ISM device to determine the presence of any significant vertical lobes of RF radiation on the 4th harmonic of the operating frequency.

Additionally, based on previous studies performed to determine the localizer receiver susceptability of various receivers, comments and recommendations were made to indicate the ability to provide co-channel interference protection from ISM devices to ILS localizer facilities. Additional comments were made regarding the feasibility and cost of performing such measurements using an aircraft and the quality of the measured data vs. the cost.

The measurements, analysis, and recommendations presented in this report are all derived from the four ISM devices tested. The best procedure, method, and equipment available were used consistent with good engineering practice. As with most engineering programs, there is always one more test or refinement possible; this one is no exception. There are still more measurements that desirably could be made to evaluate the suitability of FCC vs. CISPR measurement methods. Nevertheless, this report will present answers to those questions and will state that some others must still be asked.

II. CONCLUSIONS AND RECOMMENDATIONS

A. CISPR and FCC Testing.

With regard to the ground-based measured data, all four of the ISM devices tested at the open field test site at Waterman, Illinois, passed the FCC radiated-emissions tests. Two ISM devices passed the CISPR radiated emissions tests. The airborne tests indicate that a different situation exists. None of the ISM equipment could pass either the FCC or CISPR emissions standards. Airborne test data indicate significantly higher field strengths than the ground-based emissions measurements. This appears to be due to RF absorption for low elevation angles and the E-field boundary conditions for receiving antennas close to a ground plane.

In considering that the measured RF fields above the ISM device can be 20 to 40 dB higher than the RF fields measured on the ground, it is possible for the ISM signal to be 2.8 dB higher than the 91 dBμV/m RF field measured from the ILS localizer at Ohio University. This is based on the minimum measured air-to-ground RF field difference indicated by Table 2 of 16.9 dB higher than measurements made on the ground. If this value is added to the FCC maximum allowable field at 200 feet over the ISM device (76.9 dBμV/m) the result is 93.8 dBμV/m. The measured field strength of the localizer at Ohio University is 91 dBμV/m as explained above. This difference (93.8 - 91.0) indicates that the ISM co-channel interference is 2.8 dB above the ILS localizer signal.

The equivalent CISPR comparison produces an interference signal level of 58.6 dBμV/m which results in a localizer-to-interference signal ratio of 32.4 dB.

In all of the above FCC emissions-related considerations, there appears to be no ability to protect the aeronautical user for certain conditions of ISM placement in the service volume of the localizer.

B. Ground vs. Airborne Measurements.

Based on the measurement data from the ground-based FCC tests and the airborne tests performed, it is clear that the RF fields existing at vertical angles surrounding an ISM device are substantially higher than the RF fields measured on the ground. The specific difference amounts to measured RF fields between 20 and 40 dB higher than those measured in tests on the ground. This indicates that the current FCC measurement methods are not adequate to protect aeronautical users for certain locations of ISM equipment near localizer facilities.

Based on the equipment tested, some of the devices exhibited higher RF emissions when shields were in place than when shields were removed, at certain frequencies. Additionally, the absolute RF fields radiated at 109 MHz were significantly higher than at 27 MHz for certain devices. This indicates the need for careful design of RF shielding for these devices.

C. Difficulty and Expense of Airborne Measurements.

The cost of making airborne RF field measurements may not be significant depending on the type of ISM equipment being measured and the location of the equipment to be measured. There are alternatives to making airborne measurements, but these methods provide less complete data relating to the presence and levels of RF fields existing above the ISM equipment. A device comparable to the Clark tower could be used to determine the fields that exist at higher elevation angles, but this method does not provide measurement capability directly over the measured device. If the ISM device is being measured at a site that employs a turntable, using the Clark tower-type device is relatively easy, since the tower can be positioned and the device under test can be rotated on the turntable to make azimuth measurements.

If the device to be tested is located at an operational site, the problem of making these measurements is more significant using the Clark tower-type device. In order to make the measurements, the tower must be moved for each measurement, which is a very time-consuming activity. In this case it may be more cost effective to make the measurements from an aircraft. Most aircraft are already equipped with VHF antennas that can make the necessary measurement of the 4th harmonic of the ISM fundamental frequency, and methods do exist that allow calibration of the antenna. It is estimated that the airborne survey, including calibration of the antenna, could be completed with as little as 2.75 hours of flight time. For a single-engine aircraft capable of this operation the total costs of renting an aircraft, including a pilot and engineering labor, would be approximately $500 for the complete flight test. This assumes that the necessary receiving equipment is already available. This is not an unusual criterion since the receiving equipment is already required for the ground test procedures. To perform the same number of azimuth measurements using the Clark tower device and estimating 2 hours per measurement total using 2 people at $20/hour, the labor costs would equate to $1440. Additionally, the measurements would take 4.5 chronological days to complete; whereas the flight test data would take less than a day.

It appears that the cost of making the flight measurements is offset by the higher total cost of using a ground-based test device such as the Clark tower. The additional benefit of using the aircraft is that more complete measurements can be made of the RF fields that exist above the ISM device in a shorter time span. If ground based measurement procedures are improved so that adequate prediction of RF fields existing over the equipment can be made, then the need for airborne measurements could be eliminated.

III. AIRBORNE DATA COLLECTION SYSTEM

The data collection system configuration (shown in Figure 1) consists of a Heath H89 computer that controls several peripheral devices to collect and record relevant data. These data are the RF E-field amplitude, frequency, the aircraft position, and time of measurement. The H89 is a complete functional computer that supports a console screen, console keyboard, multiple disk drives, and three RS-232 ports. In addition, FORTH is available for use on the H89. The use of FORTH has resulted in a reduced software development time as compared to assembler with faster execution time compared to BASIC.

To measure the RF interference levels, an Electro-Metrics EMC-25 interference analyzer is incorporated into the system. The EMC-25 is designed for use as the major component of interference analysis systems from 14 kHz to 1 GHz. The receiver is tunable in 15 frequency bands for the range specified and is capable of measuring signal levels from 0 dBμV to 120 dBμV within ±1.5 dBμV at frequencies above 25 MHz (-20 dBμV to 100 dBμV below 25 MHz).

Signals provided by the EMC-25 to indicate received signal amplitudes and frequency are dc voltage levels of 0 to +1.5 V nominal. The dc voltage signal for the amplitude is derived from the meter terminal voltage and therefore is an indication of the meter deflection, while the frequency signal is a measure of the tuner setting. In addition to the above signals, there are four binary data lines encoded as a hexadecimal digit that indicates the frequency band number, and seven binary data lines from the attenuator switch. Each data line from the attenuator switch indicates that a particular attenuator setting has been selected. These seven data lines are encoded by an 8 to 3 line encoder to give a 3-bit octal representation of the attenuator switch position. The EMC-25 also contains a rechargeable battery pack as a power source that will provide enough power for the unit to operate approximately 12 hours between charges. This is an important consideration when operating in a small airplane.

A Serial Lab Products SL-803-A Intelligent Remote Serial i/o unit is used to convert the analog signals from the EMC-25 into ASCII characters and to make available upon request all EMC-25 signals on a RS-232 data communications link. The SL-803-A was chosen for its wide range of capabilities and for its ease of application. Up to 16 channels of analog data and eight digital input lines may be used. This exceeds the requirement for two channels for a/d conversion and seven digital input lines. The SL-803-A is controlled by characters sent over the RS-232 line, and it is transparent to any transmission until it detects an ASCII character that has been selected by the user as its control character. Then it reads the subsequent ASCII codes and acts according to the designed command convention. Among the programmable modes of the unit are enabling of specified channels and the selection of either ±2 V or ±10 V a/d conversion.

For the RF field measurement to be useful in determining the propagation pattern, the position of each measurement must be recorded. A Motorola Miniranger with telemetry data link is used to measure the

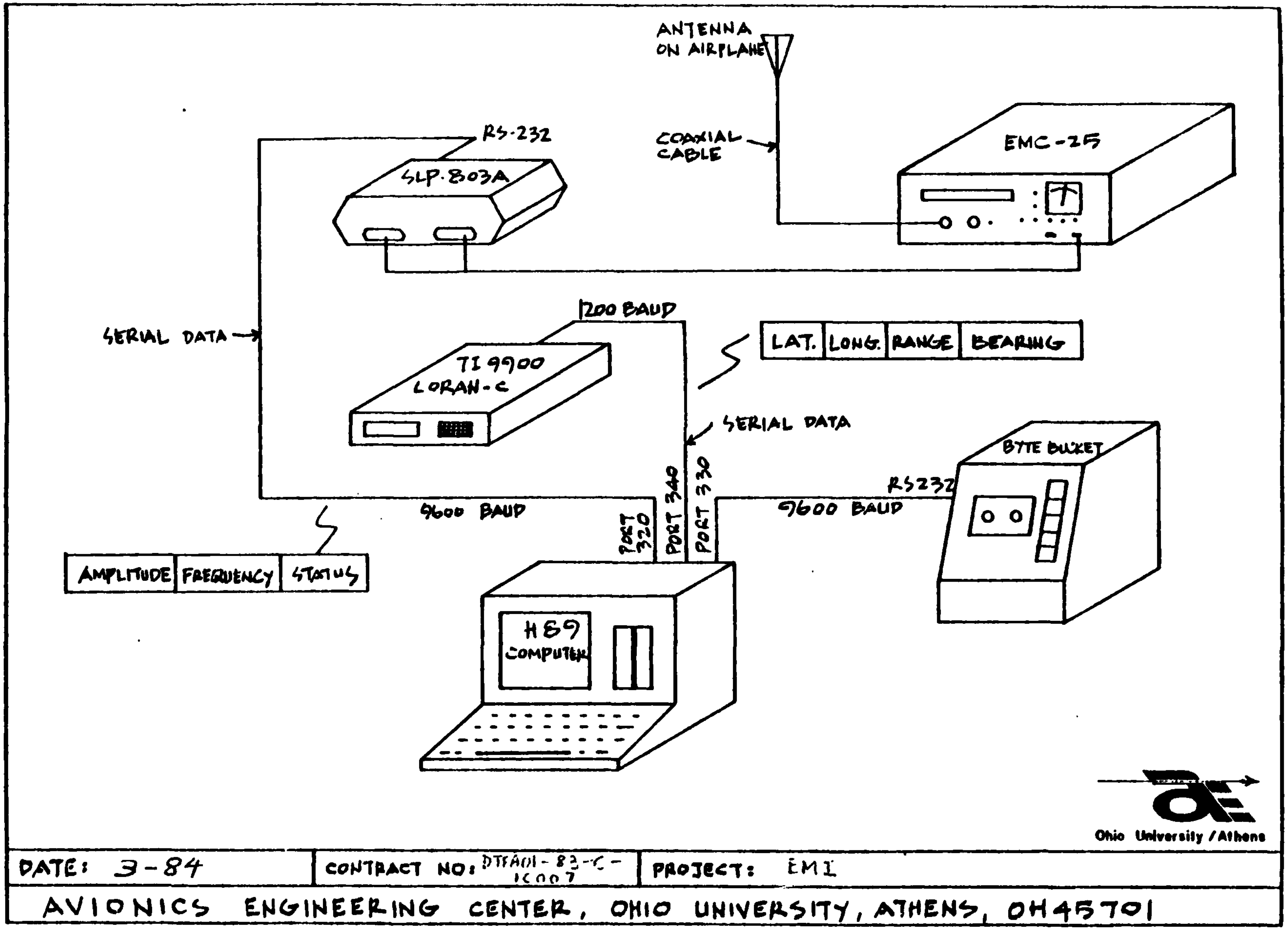


Figure 1. Data Acquisition Block Diagram

distance from a ground point to the airplane while the altitude and airplane heading are manually read from the navigation equipment in the airplane. In performing the data collection maneuvers, the pilot flies in a straight line at a constant altitude directly over the test site. When this is done, the position in space at every point can be calculated from the recorded altitude, magnetic bearing, and Miniranger distance.

The Miniranger provides a measurement of distance between the two Miniranger transponders accurate to ±2 meters and outputs the computation of the range in ASCII characters from the base unit. The Miniranger system data link is a transparent two-way communication link which is used in this system to transmit ASCII characters between the SL-803-A in the airplane and the H89 computer on the ground. For this system the Miniranger transponder will be in the airplane and the base station on the ground with H89 computer and ADPI Byte Bucket tape drive. The SL-803-A, located in the airplane, communicates with the H89 computer by sending and receiving characters over the Miniranger telemetry data link.

Airborne data collection for the tests at Waterman, Illinois, was conducted using the system described here except that the position was recorded using a TI9900 Loran-C receiver and the H89 computer and Byte Bucket tape drive were located the airplane. For these tests the aircraft position was determined by recording the position information from the Loran-C receiver, while collecting data and then calculating the distance from the ISM unit using the position of the ISM unit measured by the Loran-C receiver.

A system clock is also kept so that the time of each measurement can be recorded with the other data. The time of day is useful in data reduction by providing evidence of data collection interruption. The clock is a software counter that keeps time via interrupts provided by the H89.

Data collected by the equipment is stored on magnetic tape by the Analog and Digital Peripherals, Inc. (ADPI) Byte Bucket digital cassette tape player/recorder. The Byte Bucket is a cassette tape drive that can be controlled by the system computer by commands sent on the RS-232 data link. The Byte Bucket uses digital cassette tapes capable of storing up to 230,000 bytes of data per side. This translates into roughly 13,000 sample points per tape.

The data transfer between peripheral devices is controlled by a routine running on the H89 computer. While performing the data collection, the routine runs in a continuous loop that inputs data from the three sources and stores it on tape. The routine also creates a display on the computer's CRT to give the operator an indication of data contents, and checks for input from the console keyboard to accept user commands. User commands are software limited to a predefined set of input that controls when data collection and data storage are enabled. Figure 2 is a photograph of the airborne data collection system used in the Waterman, Illinois, tests.

Figure 2. RF Field Strength Data Collection Equipment as Installed in N8238C for Waterman, IL. Flights

The system for measuring the distance from the unit under test to the airplane was changed after the Waterman data collection because the present system using the Miniranger provides improved accuracy, is less susceptible to operator error, and provides a direct measurement of the range. This new system with the Miniranger provides a method for measuring signal levels in space that is easy to operate and provides accurate range and signal strength data.

IV. WATERMAN DATA COLLECTION FLIGHTS

Airborne data collection was conducted at Waterman, Illinois for four pieces of ISM equipment (herein referred to as Machines A, B, C, & D). These data collection flights were performed with the ISM oriented so that the maximum lobe of radiation (as detected with ground equipment) coincided with the flight path of the airplane. Also, for Machines B, C, and D data collection flights were conducted with the ISM equipment oriented for flight paths at 60 degrees to either side of the maximum lobe. These procedures were consistent with those used in the ground-based measurements using the Clark tower. Three of the Machines (A, C, and D) were tested both with RF shielding on and off to study the effects of shielding while Machine B was tested only with shields on.

Calibration data for equipment, antennas, and cables are indicated in Table 1. For all airborne data this calibration of antennas on the aircraft is appropriate.

A. Analysis of Airborne Data.

Data collected at Waterman, Illinois, were reduced using the Ohio University IBM 370 computer system and plots of each data run were created. These plots are Figures A-1 - A-21 in Appendix A. The plots show the measured E-field in absolute dBμV/m on the ordinate versus the horizontal distance from the test site on the abscissa (refer to Figure 3 for example). The horizontal distance is the distance from a point on the ground directly beneath the airplane to the location of the ISM equipment, and the distance is shown as positive for points north of the test site and negative for points south. The horizontal distance was used to create plots rather than the slant range distance to avoid discontinuities in the graph which would result from the slant range distance ambiguity as the airplane passed over the test site. (The slant range is never less than the aircraft altitude.)

At the top of each plot is a description of the test conditions. This description identifies the machine and indicates the machine setup parameters. Shown on the data plots as dashed lines are the FCC and CISPR limits for this frequency band, calculated by extrapolating the E-field limits from their specified test distance to the distance of concern using the free space decay factor of 2.0 as follows:

$$E(R) = E_{limit}\left(\frac{D_{limit}}{R}\right)^{2.0}$$

where

$E(R)$ = E-field limit at distance R (μV/m)

E_{limit} = specified FCC or CISPR E-field limit (μV/m)

D_{limit} = distance at which E_{limit} is specified

R = distance of concern

TABLE 1. ISM MEASUREMENT TESTS CALIBRATION DATA

EMI CALIBRATION DATA
February 21, 1984

Biconical Antenna
Antenna factor = 16.4 dB @ 27 MHz
Antenna factor = 13.1 dB @ 109 MHz
Source: Three antenna method calibration. Sept. 9, 1983

Bent dipole antenna on Saratoga N8238C
Antenna factor = 53.4 dB @ 27 MHz
Antenna factor = 13.1 dB @ 109 MHz
Source: Calibration versus biconical antenna using substitution. Nov. 7, 1983

27MHz antenna on Saratoga N8238C
Antenna factor = 9 dB @ 27 MHz
Source: Data collected on January 3, 1984

Cables
EMI Cable A (35 feet)
-0.7 dB @ 27 MHz
-1.2 dB @ 109 MHz
EMI Cable B (80 feet)
-1.6 dB @ 27 MHz
-3.2 dB @ 109 MHz
EMI Cable C (5 feet)
-0.2 dB @ 27 MHz
-0.4 dB @ 109 MHz
Source: All cables calibrated Sept. 12, 1983

Dual directional coupler - HP778D serial no. 1144a04704
27 MHz - both ports -32.6 dB
109 MHz - both ports -22.0 dB

NOTE: Antenna factor is the value added to the measured field in dBμV to obtain absolute field strength in dBμV/m.

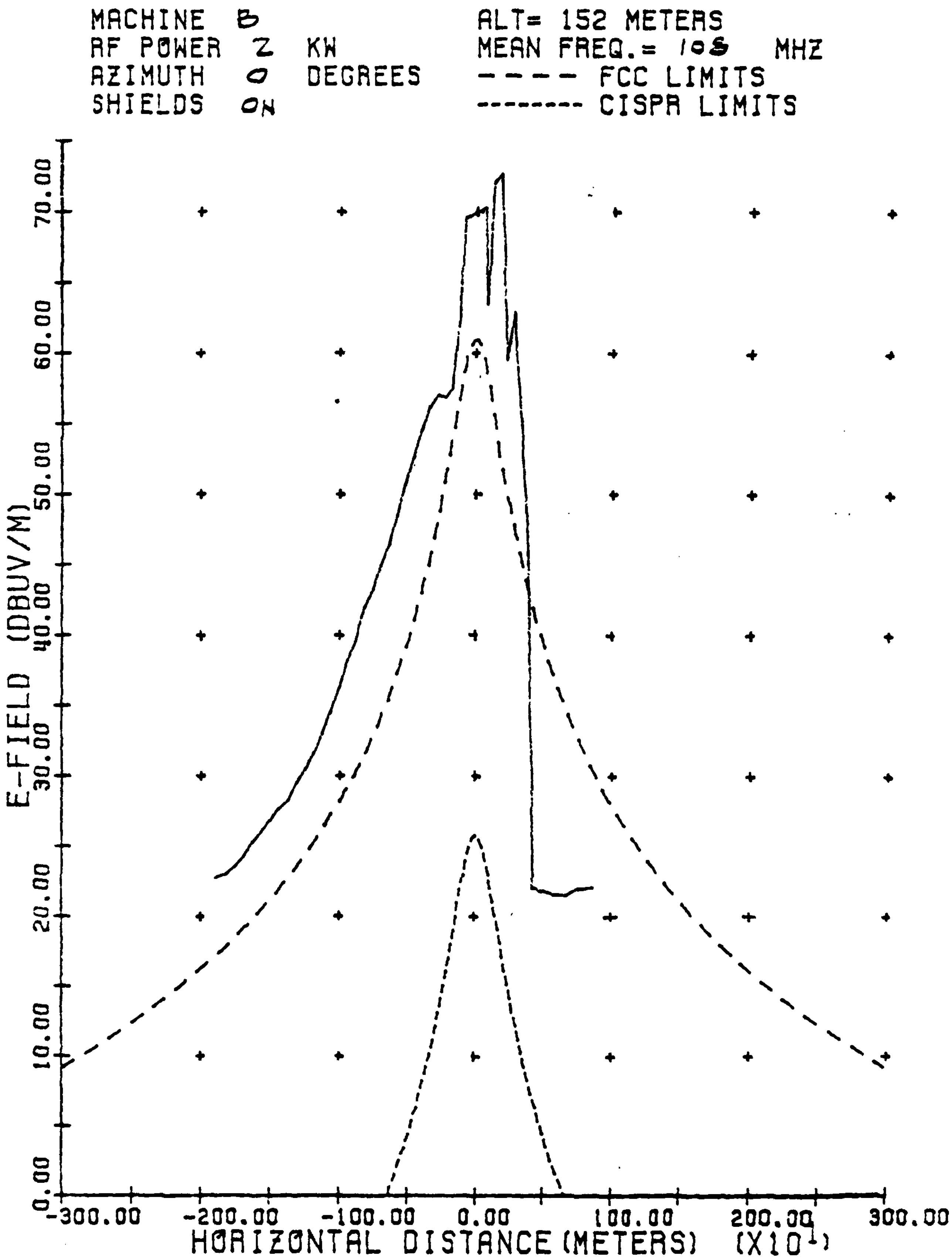


Figure 3. Flight Data Machine B, 2 kW, 152 M Altitude
0° Azimuth, RFI Shields in Place

The distance R takes into account the altitude; that is, R is equal to the slant range distance from the ISM equipment to the airplane. The plotted FCC and CISPR limits provide reference points that ease comparison of plots as well as show relevance between actual measured data and maximum permissible levels.

The ISM machines tested at Waterman, Illinois, all exhibited some degree of vertical lobing directly above the unit. The plots of Machine A (Figures A-1 - A-5) show that this machine emitted a relatively low level radiation directly overhead with a uniform higher level at elevation angles to either side of overhead. The plots of this machine's performance show levels as much as 35 dB greater than the FCC limits when some shielding was removed, compared to signal strengths of 6 dB maximum above limits when all shielding was installed properly.

Machine B plots (Figures A-6 - A-11) show that this piece of equipment had some very narrow vertical lobes directly above the unit with uniform signal levels to either side. The lobes of radiation above the unit were as much as 24 dB above FCC limits; whereas radiation to the sides was always within 10 dB of limits.

Machines C and D were the same machine except for the RF power generated; Machine C generated 3 kW of RF power and D produced 2 kW. Neither of these had any significant radiation levels overhead. The largest signal levels detected were about 7 dB above FCC limits with shields off (Figure A-16) and 5 dB above limits with all shielding in place (Figure A-12). The plots of Machine C demonstrate the effects of shielding for this unit. Comparison of Machine C plots where only the shielding is different show that the shielding suppresses the RF signal levels by about 3-7 dB (Figures A-12 to A-17). However, Machine A showed signal levels as much as 15-20 dB higher with shields off as compared to those measured when all shields were in place. This indicates that the shields for Machine A (the 25 kW unit) had a much greater effect on the radiation levels than did the shields on Machine C (a 3 kW unit). This may be due to the design of the shields since there is a lesser need for shielding on the smaller units. Shielding for larger units would naturally be more carefully designed.

The E-field values shown in Table 2 represent the measured field strengths extrapolated to one mile for easy comparison with FCC limits. The ground-based data are those measured by Elite Electronics Engineering Company (under subcontract) using FCC procedures for ISM equipment certification. The airborne data were obtained by evaluating the plots of Figures A-1 - A-22 to find the average difference between the plotted data and the FCC limits. This average difference was taken from a section of the plot that was not directly above the unit. This criterion results in the evaluation of the plots at points where the field is fairly uniform and so represents conditions which would be encountered when flying near one of these units (if flying directly overhead, the signal level could change significantly, either lower or higher). Generally, the points used to generate this table were at a horizontal distance of between -500 and -1500 meters as indicated on the figures. To maintain consistency with the conditions of ground-based measurements, only those data collected with all shielding in place were considered.

TABLE 2. GROUND VS. AIRBORNE DATA COMPARISON AT ONE MILE
dBμV/m

NOTE: FCC LIMIT = 20 dBμV/m

Machine A

Azimuth	Airborne data (dBμV/m)	Ground Data (dBμV/m)	E_{AG} (dB)
180	+25.0	-16.4	41.4

Machine B

Azimuth	Airborne data (dBμV/m)	Ground Data (dBμV/m)	E_{AG} (dB)
0	28.0	+11.1	16.9
240	27.0	+ 5.9	21.1
300	26.0	+ 5.3	20.7

Machine C

Azimuth	Airborne data (dBμV/m)	Ground Data (dBμV/m)	E_{AG} (dB)
20	+ 6.0	-19.5	25.5
260	+12.0	-15.9	27.9
320	+25.0	-15.0	40.0

Machine D

Azimuth	Airborne data (dBμV/m)	Ground Data (dBμV/m)	E_{AG} (dB)
20	+15.0	-20.8	35.8
60	+13.0	-23.3	36.3
200	+25.0	-17.9	42.9
260	+21.0	-17.2	38.2
320	+22.0	-14.5	36.5

E_{AG} = Airborne field strength (dBμV/m) - Ground field strength (dBμV/m)

In all cases shown in Table 2, the airborne data are much higher than the ground measurements. This difference ranges from 16.9 dB for Machine B at 0 degree to 42.9 dB for Machine D at 200 degrees. Data for Machines B and D show that the difference between ground-based and airborne measurements was relatively constant with respect to azimuth for these two machines. For Machine B the airborne measurements ranged from 16.9 to 21.1 dB above ground-based measurements, and airborne measurements for Machine D ranged from 35.8 to 42.9 dB above ground-based measurements (Machine B was tested at three different azimuths and Machine D was tested at five). This seems to indicate that the lobing patterns measured on the ground also exist in the air but with different magnitudes.

The plots of data collected at Waterman, Illinois, exhibit a great deal of consistency concerning the detection of vertical lobing. Every plot shows some amount of lobing at points directly above the unit and a more uniform field at lower elevation angles. The plots indicate that these machines emit a somewhat uniform field with respect to both elevation angle and azimuth (the elevation angles in the plots are always greater than 2.9 degrees). The only lobing with respect to elevation angle is seen directly above the unit. This is similar to the lobing seen from a dipole antenna caused by interaction with the ground plane (see Figure 4). This figure indicates the relative field strength seen by an aircraft making a level pass at 500 feet over the RF source placed 7 feet above the ground [1]. Due to the complex nature of the radiation from ISM equipment, it is expected that a more complex interference pattern would be observed for RF fields directly over the ISM equipment. Machines B, C, and D were tested at different azimuths and each displayed a general uniformity of signal levels. Machine D was tested at five different azimuths and, in each case, the received signal was within 5 dB of the FCC limits; however, Machine C did display a significant null at 20 degrees.

Based on the data collected for the four ISM units at Waterman, Illinois, it is seen that the determination of the signal levels in space produced by a piece of ISM equipment can be measured accurately by flying over the site. The resolution of the data collection system is sufficient to detect most lobing that is present. Additionally, data from the Waterman flight tests seem to indicate that there are no extremely sharp lobes of high level radiation. Since the signal levels measured in the airborne tests were consistently much larger than those measured on the ground, it seems likely that airborne measurements of the ISM interference signals provide a more accurate measure of the field strengths at high angles than do the ground-based measurements.

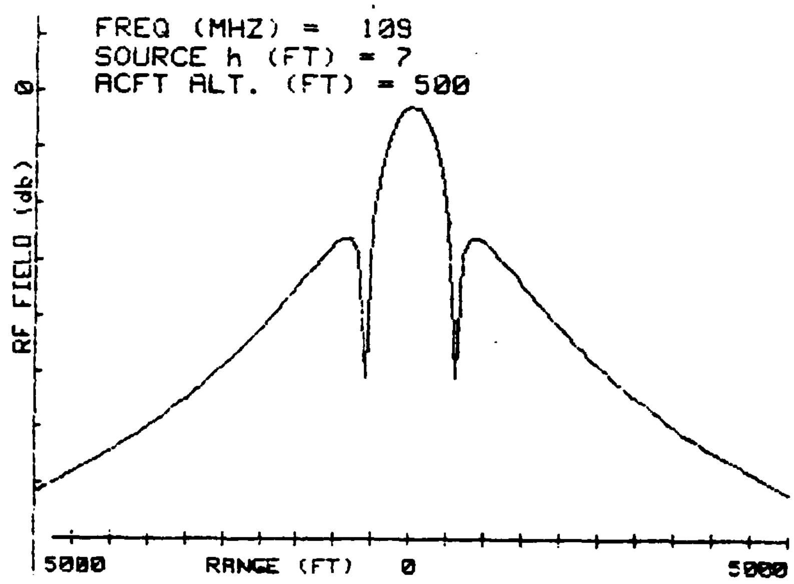


Figure 4. Theoretical RF Field Interference Pattern Seen by Aircraft Making Level Pass at 500 ft. with RF Source at 7 ft. Above Ground

V. FCC AND CISPR RADIATED EMISSIONS MEASUREMENTS

A. Test Procedures and Sample Calculations.

1. Open Field Measurements. Measurements were performed at 20 degree increments by turning the units on an air table. Measurements were taken at the fundamental frequency and at all harmonics through the 10th harmonic. These data were extrapolated to equivalent readings at 1 mile by using a field decay exponent of 1.95. This decay factor was determined by actual measurement at ground level.

All measurements were performed with the dielectric sealer in a continuous mode of operation (1-minute operation) with a silicon load between the plates. This was done for ease of measurement.

These units were tested at Elite Electronic Engineering Company's Waterman, Illinois, test site (EQU/6810 4-3-0 Elite Engineering Waterman).

2. Distance Correction Calculations. The field intensity limit imposed by the FCC Rules and Regulations is 10 microvolts per meter at 1 mile. Since the data cannot always be taken at 1 mile and since the field intensity from the item is often too weak to be measured at greater distances, especially in the presence of other noise, these data were taken at some closer distance and the field intensity was extrapolated to 1 mile using equation 1. See FCC "Rules and Regulations," Volume II, Part 18, Subpart D, para. 18.107 (c).

The propagation decay constant is determined by plotting measured field strength in dBμV vs. distance in feet and then drawing an average curve through these points. The slope of this curve is the measured decay constant n. For an example, see Appendix B.

With a measured decay constant n, the correction to a distance of 1 mile from any distance D takes the form:

$$L_2 = L_1 \, (5280/D)^{-n} \qquad (1)$$

L_2 = Field intensity at 5280 ft.
L_1 = Measured field intensity at distance D
n = Measured decay constant

All data recorded on the data sheets were corrected to equivalent readings at 1 mile. The distance correction factor to convert from 200 feet to 1 mile reduced to -55.4 dB.

The test specification also requires a plot of the equivalent field intensity pattern at 1000 feet to be plotted. The data taken at the fundamental frequency at each azimuth were corrected to equivalent readings at 1000 feet to provide the necessary levels to compose the pattern. See Figure 6 for an example.

To facilitate the computations which involve antenna factors, calibration factors, and distance factors, the field intensity is first computed in dBμV/m and then converted to μV/m for comparison to the limits.

To obtain the field intensity at a standard distance, the following factors (in dB) are added:

Meter Reading: Obtained from the field intensity meter

+Antenna Factor: Supplied by manufacturer of antenna to convert voltage measured at antenna terminals to equivalent volts/meter field intensity

+Distance Correction Factor: Explained above
=Total in dBμV/m

This total is converted to μV/m using the well-known anti-log conversion.

$$E(\mu V/m) = 10^{\left[\frac{E(dB\mu V/m)}{20}\right]}$$

B. CISPR vs. FCC Measurement Procedures.

The significant difference in the FCC and CISPR measurement procedures is the distances that the measurements are specified [2,3,4]. Since the RF radiation from the ISM devices measured at Waterman, Illinois, was CW, there is no difference in the effective field strengths for CISPR or FCC. The significantly lower CISPR limits seem to be an attempt to account for the fact that when making measurements using an antenna relatively close to the ground, the actual RF field will be higher than indicated for elevation angles above the horizon. Since CISPR specifies measurements at 30 and 100 meters and uses lower radiated limits, the effect at higher elevation angles is that the allowable RF field strength will better represent the line-of-sight RF fields that will exist. The measurements made according to FCC specifications on the ground and extrapolated to 1 mile may be significantly lower than the fields that exist along a direct line from the unit under test to an aircraft 500 feet or more above the local terrain. It may appear that the CISPR specifications seem to be overly conservative, but they may better protect the aeronautical user since this radiation measurement procedure can better represent the actual launched RF energy when the effect of placing the sensing antenna relatively close to the ground is considered.

This issue of the adoption of CISPR vs. FCC radiation limits is very controversial and needs significant attention. The initial data measurements presented by this report point to the need for additional RF radiation measurement procedures for ISM equipment based on FCC limits on interference to ILS localizer facilities.

1. FCC and CISPR ISM Equipment Description. During the open field testing at Waterman, Illinois, four pieces of ISM equipment were tested with the following power output ratings:

MODEL A 25 kW OUTPUT
MODEL B 2 kW OUTPUT
MODEL C 3 kW OUTPUT
MODEL D 2 kW OUTPUT

All of the ground measurement data sheets which include RF field measurements through the 10th harmonic are included in Appendix B. The data included here are the radiation pattern measurements at 1000 feet, indicating the shape of the radiation pattern for both the fundamental operating frequency and the 4th harmonic. The data to generate these plots are derived directly from the ground measurement data sheets contained in Appendix B.

The ground measurement equipment placement for the FCC and CISPR measurements is shown graphically in Figure 5. The biconical antenna used for the ground measurements was placed, for most tests, 200 feet from the ISM device to be measured. The ISM device was set up on the turntable in the building with the position of the operator considered as 0 degree azimuth. After each measurement was made, the ISM device was rotated to the next azimuth angle on the turntable to be measured. In this manner the complete FCC and CISPR emissions tests were made for the device. These results then provided the horizontal lobe of maximum radiation to be considered in the Clark tower and airborne testing.

The spectrum analyzer, its computer and printer, were operated from the instrumentation van by Elite Electronic Engineering Company personnel. This is definitely the most efficient method to make these measurements. The turntable speeds up the positioning of the equipment and the computer-controlled spectrum analyzer speeds up the data-taking and recording. Once the equipment is set up the actual ground testing can be performed in less than an hour on a specific ISM device.

2. FCC and CISPR Emissions Measurements Results. Figures 6 through 13 are the polar plots of the radiation patterns of each of the four ISM devices at the fundamental and 4th harmonic of the fundamental operating frequency. These data indicate that all of the ISM devices are within the FCC specification for allowable emissions on the 4th harmonic of the operating frequency. The emissions limit, except for fundamental, extrapolated from 1 mile to the 1000-foot position is 257 μV/m. This extrapolation was performed using the decay exponent determined by actual ground measurement. A plot of the decay exponent measurement is included in the data for each device contained in Appendix B. The CISPR limit extrapolated to 1000 feet in a similar way produces a limit of 5.4 μV/m. With this limit in mind only Models C and D, Figures 11 and 13, pass the radiated emissions tests for CISPR. Models A and B, Figures 7 and 9, exceed CISPR limits for radiated emissions at the 4th harmonic. This can be seen by referring to the plots for the emissions patterns at the 4th harmonic. Also of particular note is that there is a considerable amount of correlation between the pattern at 27 MHz and at 108 MHz for ISM Model A, Figures 6 and 7. Prominent RF radiation peaks correlate well between the patterns at the two frequencies. This does not occur when comparing the patterns with any of the other ISM devices, Figures 8 thru 13. It is not clear why only one of the ISM devices produces a pattern correlation. As was expected, the radiation patterns are quite complex.

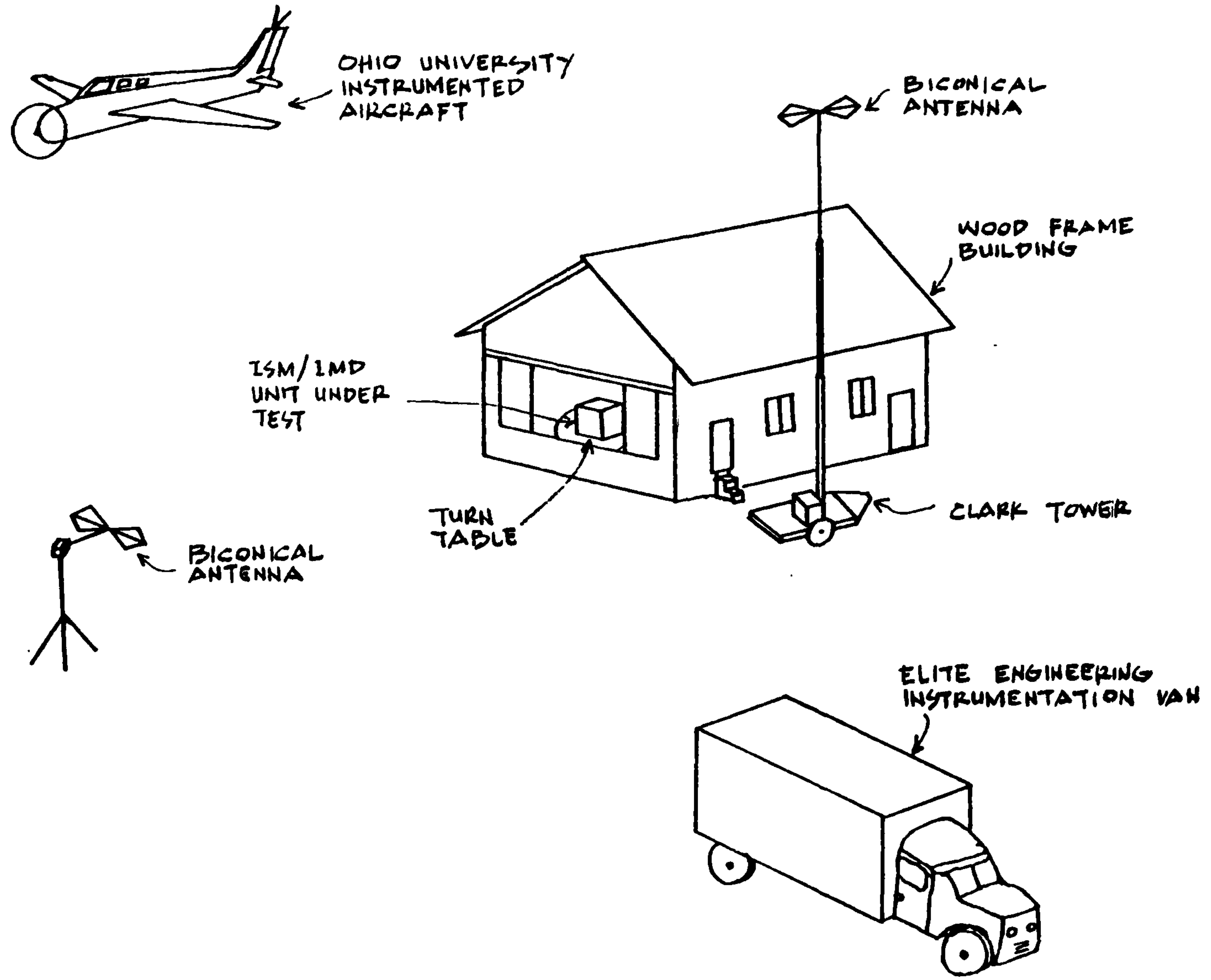


Figure 5. Diagram of Ground, Clark Tower, and Flight Measurement Equipment Setup at Waterman, Illinois

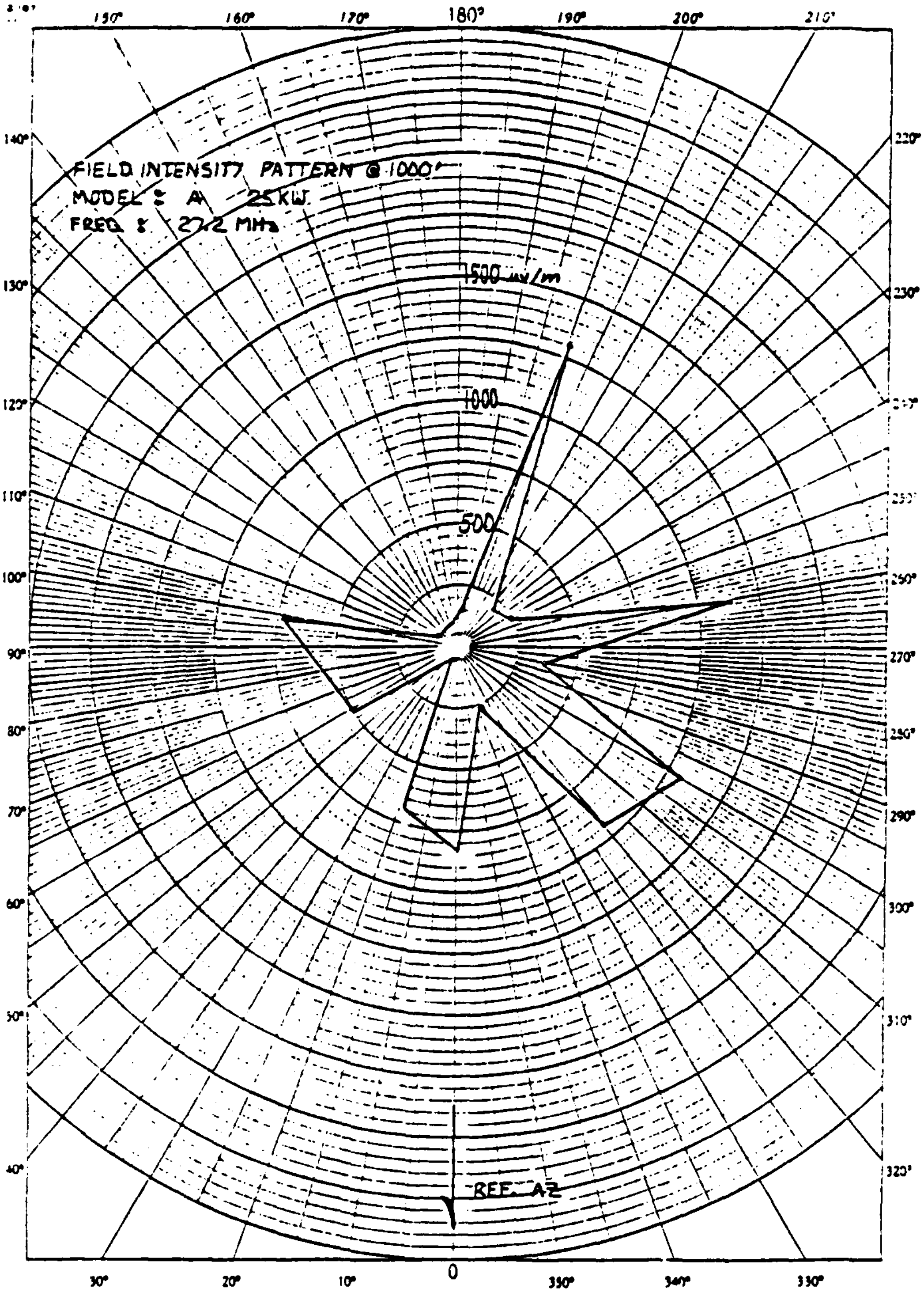


Figure 6. Fundamental Field Intensity Pattern at 1000 ft. for Model A, 25 kW

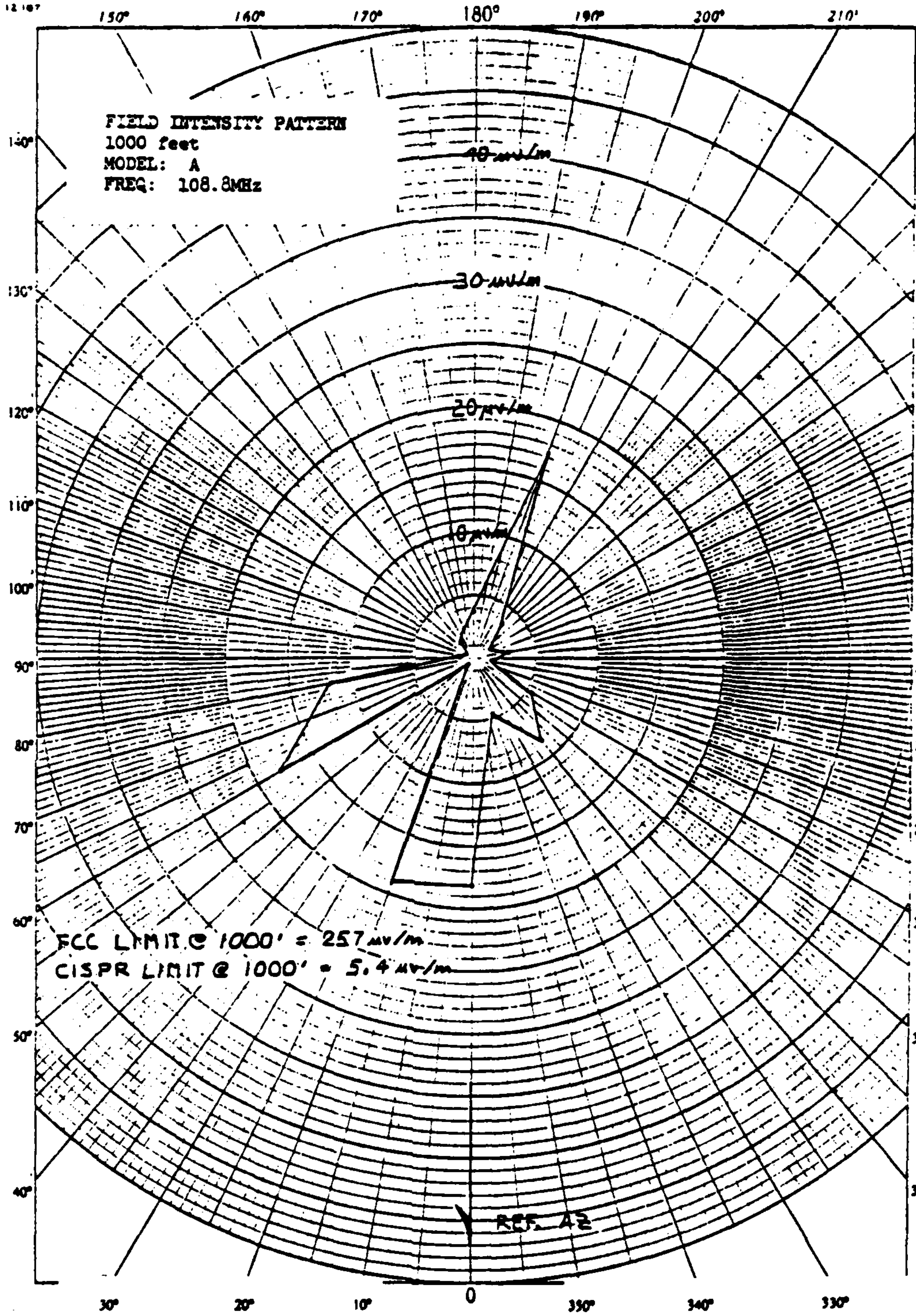


Figure 7. 4th Harmonic Field Intensity Pattern at 1000 ft. for Model A, 25 kW

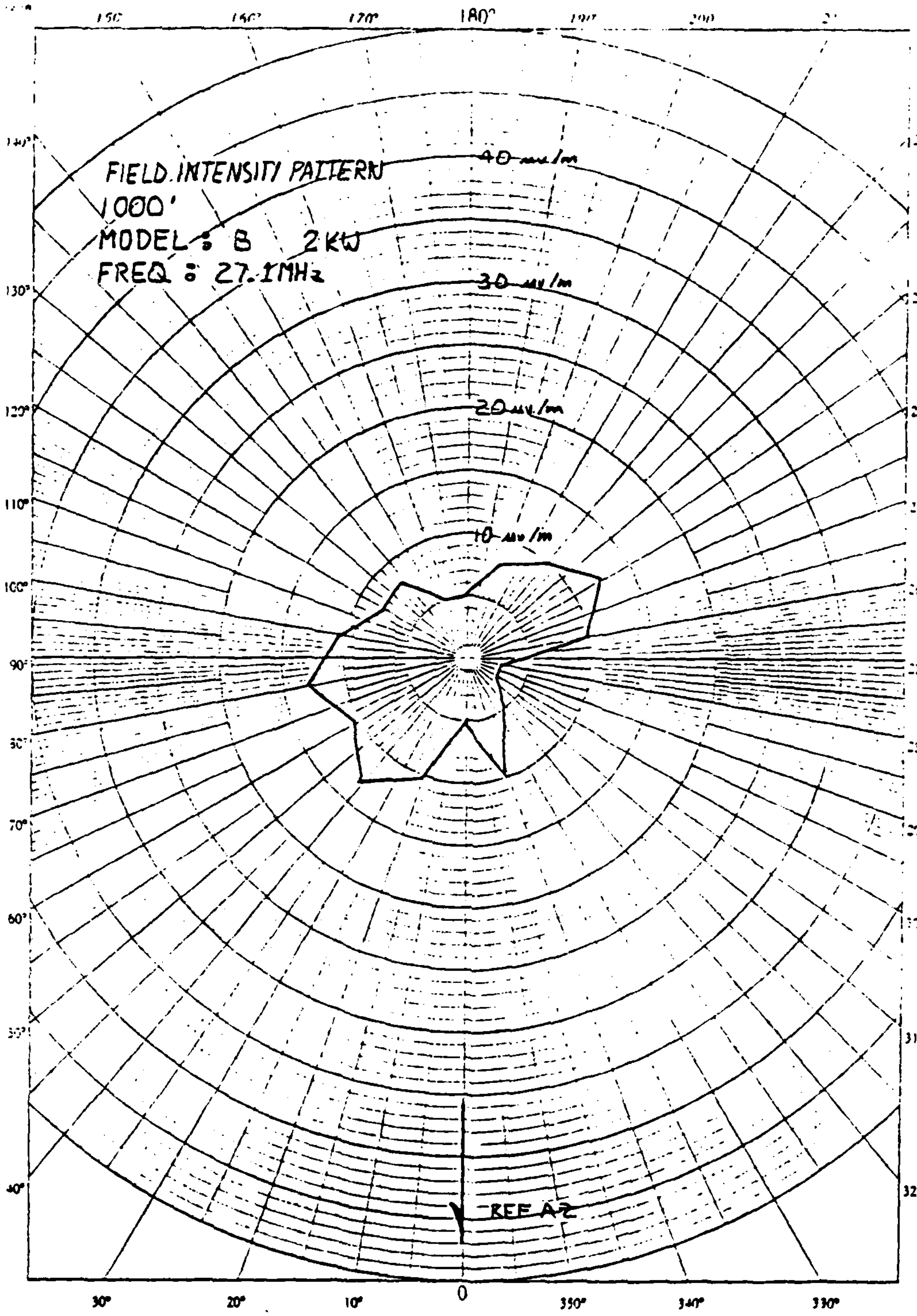


Figure 8. Fundamental Field Intensity Pattern at 1000 ft. for Model B, 2 kW

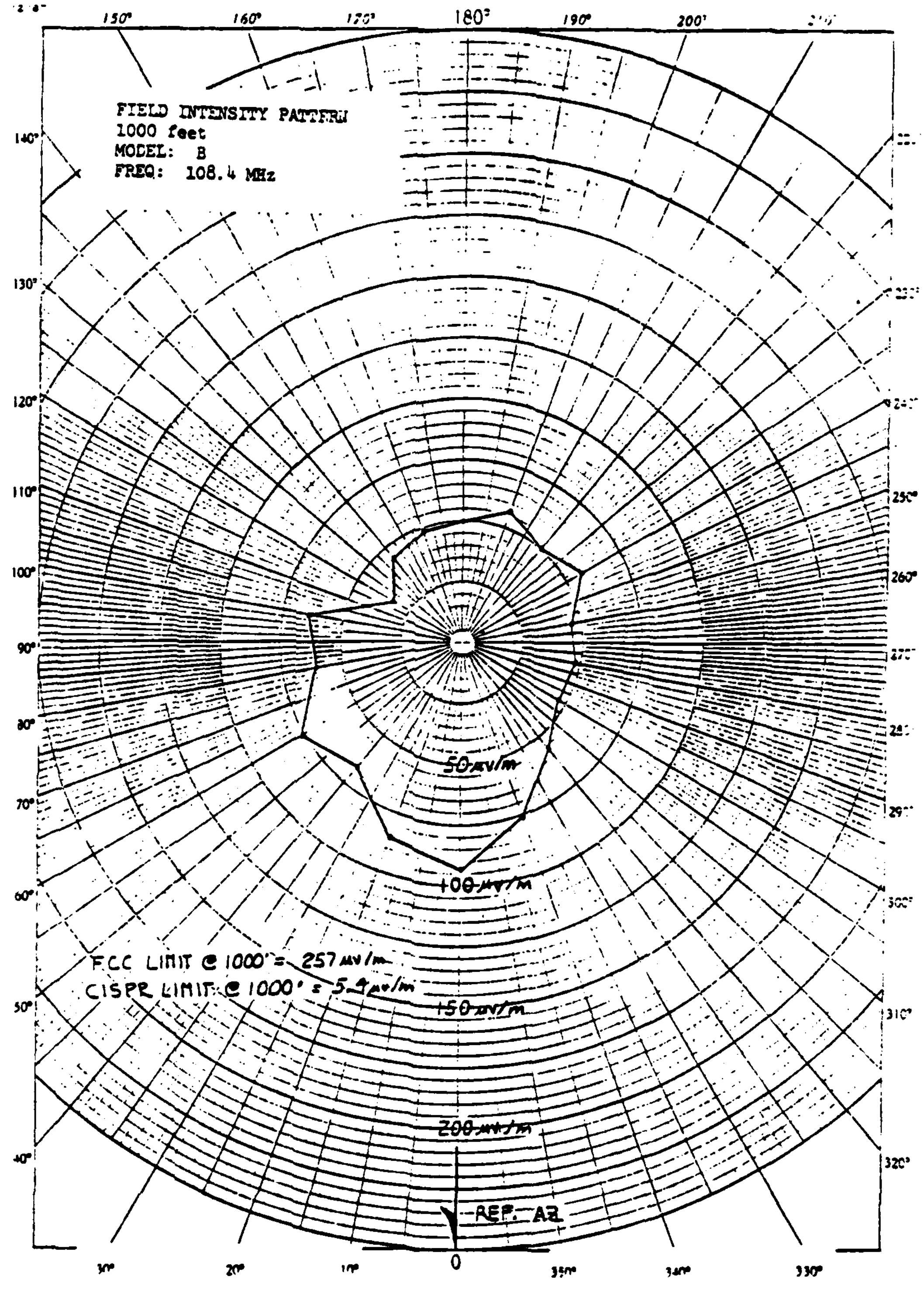


Figure 9. 4th Harmonic Field Intensity Pattern at 1000 ft. for Model B, 2 kW

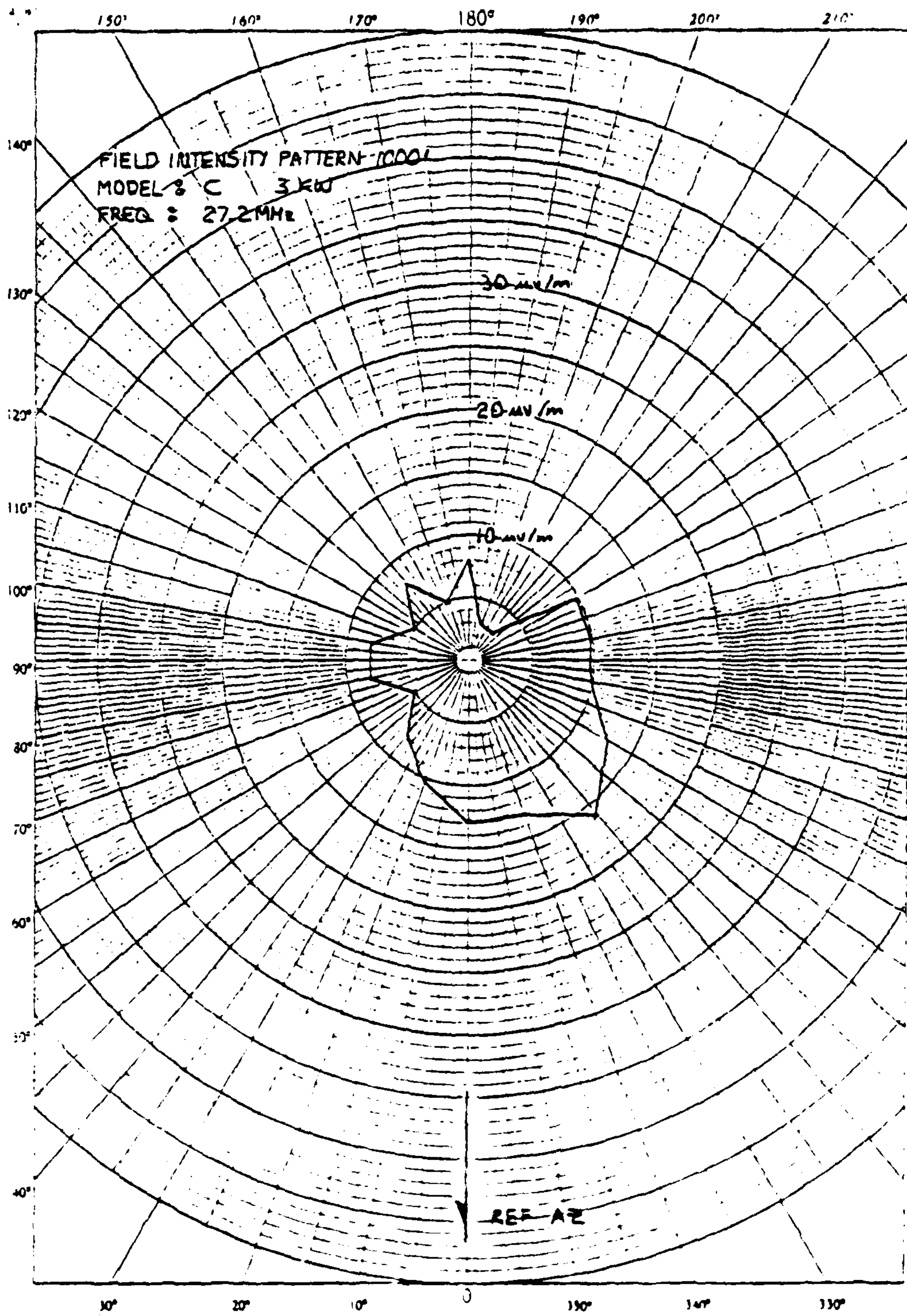


Figure 10. Fundamental Field Intensity Pattern at 1000 ft. for Model C, 3 kW

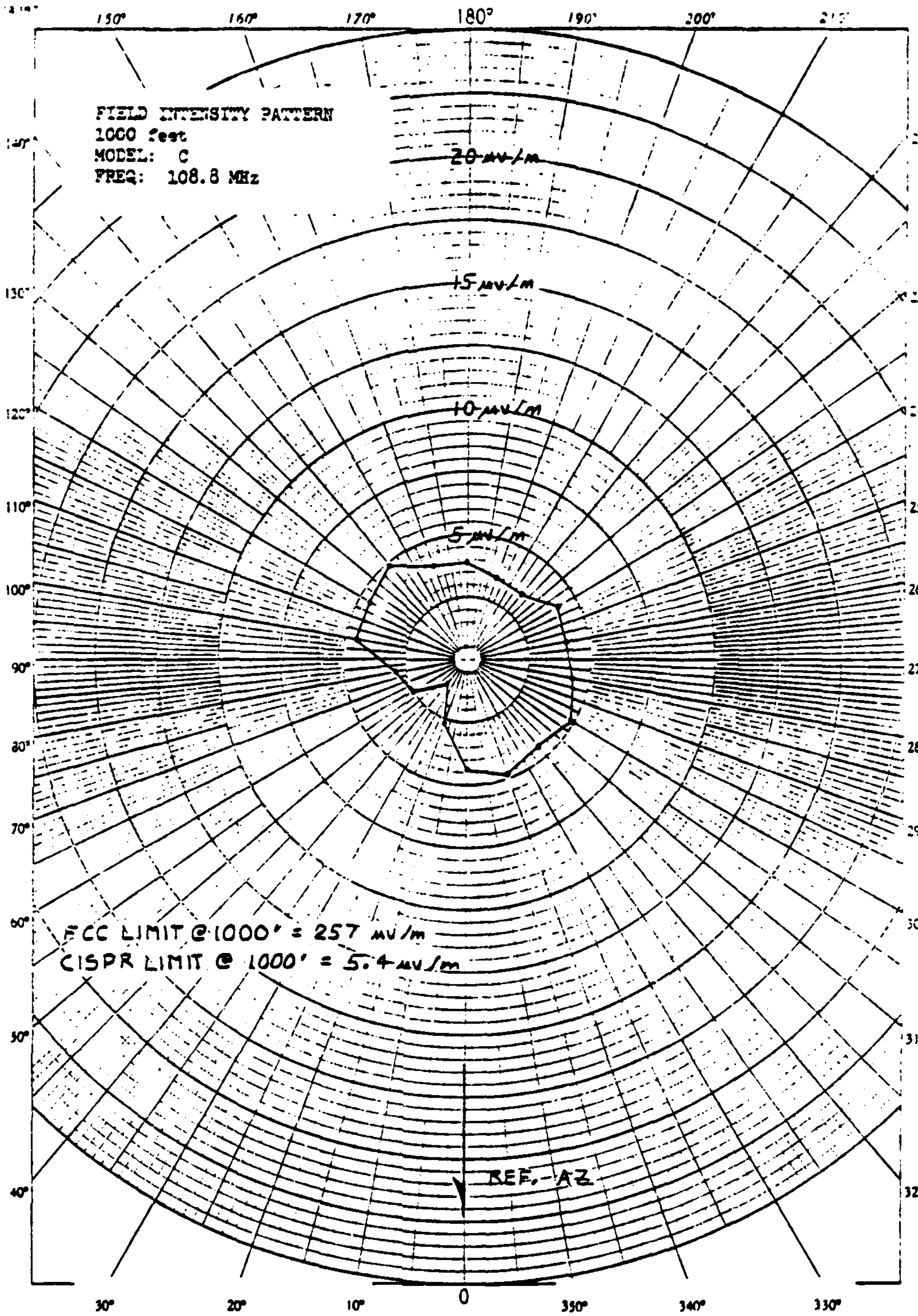


Figure 11. 4th Harmonic Field Intensity Pattern at 1000ft. for Model C, 3 kW

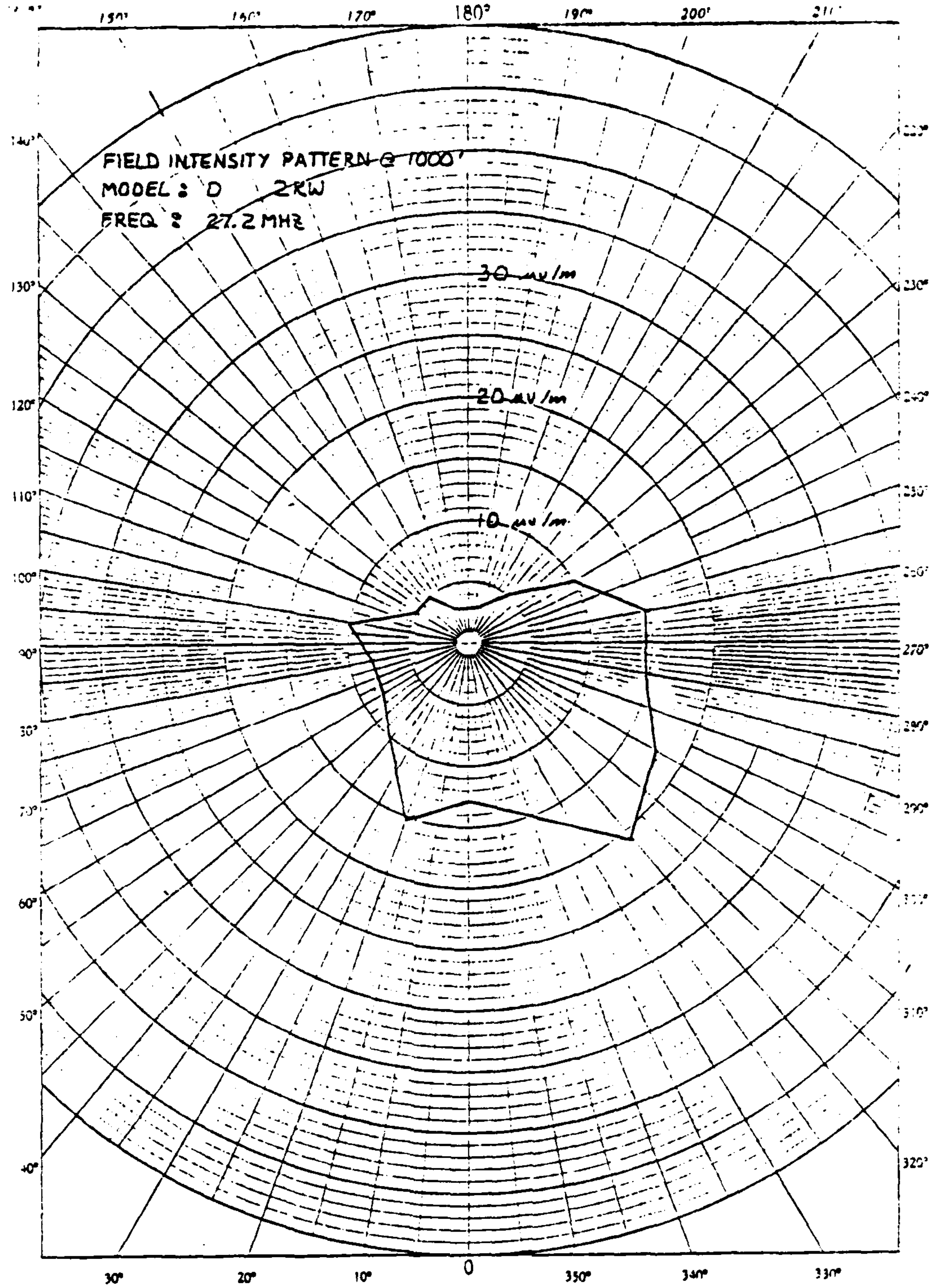


Figure 12. Fundamental Field Intensity Pattern at 1000 ft. for Model D, 2 kW

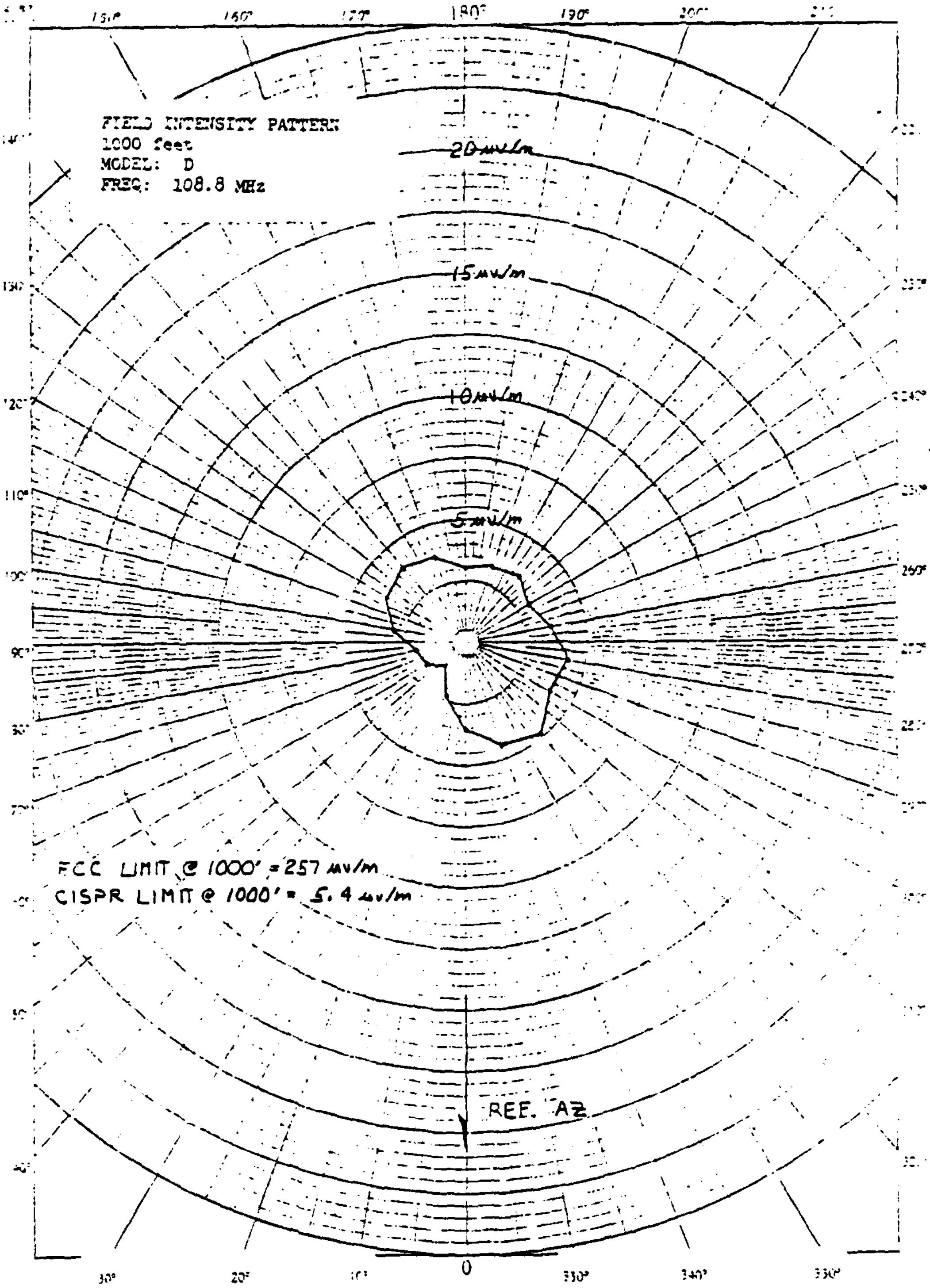


Figure 13. 4th Harmonic Field Intensity Pattern at 1000 ft. for Model D, 2 kW

All of the results reported in this section are for the equipment operating as per manufacturer's specifications with all radio frequency interference (RFI) shielding in place.

During the course of comparing the ground measurements and the airborne measurements two effects were observed. First, in all of the airborne measurements, as the aircraft passed directly over the equipment under test, a pattern of nulls and peaks was observed. This was due mainly to the interferometer pattern that was a result of the interaction of the RF source of the ISM equipment interacting with the apparent image source produced by the effects of the ground plane. As the apparent height of the radiating source was located at specific fractions or multiples of the wavelength, an interference pattern of nulls and peaks was formed. This was caused by the differences in the effective paths that the RF energy took to appear at the aircraft antenna position. If the path lengths differ by exactly 1/2 wavelength, the two waves will cancel; and conversely, if the path lengths are 1 wavelength different, then the two waves will add. Therefore, it is easy to understand that for certain geometries the RF energy will appear to produce peaks and nulls. Examining the geometry of the area directly above the ISM equipment, it can be seen that the radiation source and its image are more likely to form these interference patterns since the wave path length differences are greater at this point than when the aircraft is at lower elevation angles. In light of this, it is clear that in the areas near vertical above the ISM device, the fields can have significant peak-to-peak excursions, but these are true fields and need to be considered when flights over ISM equipment are possible.

The second effect involved a much more subtle consideration but was certainly more significant. Differences in the ground measured data as compared to the airborne measured data for angles greater than about 5-10 degrees up to almost 90 degrees were found. As was determined by previous measurements, the airborne data were some 20 to 40 dB above ground measured data. This may be due to the fact that the radiation measured by the ground tests may be in error of the actual RF fields because at the 100 MHz frequency range the earth conductivity may appear as a lossy dielectric, and the RF fields are attenuated when the receiving antenna is relatively close to the ground. Additionally, considering the antenna patterns of horizontally polarized antennas, it can also be seen that at low elevation angles there is very little RF radiation. This is due to the requirements to satisfy the E-field boundary conditions for horizontally polarized waves. This effect is not the case for vertically polarized waves, but the effects of the ground as a lossy dielectric will generally be of greater importance here. Therefore, it is necessary that these effects be considered when applying procedures used by the FCC and CISPR to make the ground measurements.

VI. CLARK TOWER OPEN-FIELD TEST PROCEDURES

In order to determine (from the ground) the presence of higher-angle radiation from the ISM unit under test (UUT), a device capable of hoisting an antenna from heights of about 20 feet to 70 feet was used. The tower with the antenna on top was raised to various heights so that the RF field could be sampled. The tower was placed close to the building containing the UUT so that elevation angles up to approximately 75 degrees could be measured.

A. Test Equipment.

The test equipment used during this series of tests consists of the following:

1. HP 8568 spectrum analyzer SN 1818A00258 Cal 4-9-83
2. HP 9825 computer SN 1541A00350
3. HP 2631B line printer SN 2002A00184
4. EMCO biconical antenna SN 2171
5. Clark tower pneumatic antenna positioning equipment

B. Procedures.

The Clark tower with the Electro-Mechanics Company (EMCO) biconical antenna mounted on top was positioned 15.75 feet from the center of the turntable used to turn the equipment under test. The tower was positioned at 90 degrees from the direction that the ground RF measurements were made. When tower measurements of the equipment were made, the azimuth indicated in the Clark tower measurements data was the same as the ground measurements data since the turntable was positioned without the 90-degree offset in azimuth.

The Clark tower base was not at the same level as the equipment under test and therefore the Clark tower height is not the same as the vertical separation of the equipment under test and the antenna on the Clark tower. The difference between the base of the Clark tower and the base of the equipment under test was 4 feet. All of the data plots for the Clark tower take this distance difference into account.

Operation of the equipment under test was essentially the same as that in the airborne and ground testing. The ISM equipment was turned on and the RF field measurements were made with the tower at a specific height. The measurements with the Clark tower were made at heights above the base of the tower of 20 feet, 30 feet, 40 feet, 50 feet, and 60 feet, with the azimuth corresponding to the measured maximum RF field from the ground measurements. Also, measurements were made 60 degrees to either side of the maximum RF field. Taking into account the difference in the heights of the bases of the equipment under test and the Clark tower, the measured elevation angles correspond to 46 degrees, 59 degrees, 66 degrees, 71 degrees, and 74 degrees. Refer to Figure 5 which indicates the position of Clark tower relative to equipment under test.

The RF measurement device was the HP 8568 spectrum analyzer along with the Elite cable plus the OU 80-foot cable. The data printouts from the Elite spectrum analyzer did not account for the EMCO biconical antenna nor the 80-foot OU cable. These values were added to the measured values shown on the Elite data measurement sheets. The values for the EMCO biconical and cables are indicated in Table 1 for 27 MHz and 108 MHz.

The graphic data for the Clark tower measurements were produced by extrapolating the data measured to a common distance of 1000 ft. to allow easy interpretation. This was done by the following method. Using the ground derived decay exponent, the distance correction was determined from the following equation:

$$F2 = F1 + 20 \log \left[\frac{1000}{d}\right]^{-n}$$

where:

F1 = field intensity at slant range d in dBμV/m

F2 = field intensity at range 1000 ft. in dBμV/m

n = measured decay exponent

The distance d is the distance from the equipment under test to the biconical antenna on the Clark tower.

For example, the slant range from the equipment under test to the biconical on the Clark tower for a tower height of 40 ft. is:

$$d = \sqrt{sep^2 + (40-delth)^2}$$

$$d = 39.3 \text{ ft.}$$

where:

sep = 15.75 ft. center of turntable to center of Clark tower

delth = 4.0 ft. differential in UUT and Clark tower bases

The ground measured decay factor was 1.95. Solving for the RF field at 1000 ft. produces the following result for a measured RF field of 70 dBμV/m at the biconical antenna:

$$F2 = 70 \text{ dB}\mu\text{V/m} + 20 \log \left[\frac{1000}{39.3}\right]^{-1.95}$$

F2 = 15.2 dBμV/m or 5.74 μV/m at 1000 ft.

The following devices were tested using the Clark tower at the open field test site at Waterman, Illinois.

Model A = 25 kW ISM Device
Model B = 2 kW ISM Device
Model C = 3 kW ISM Device
Model D = 2 kW ISM Device

Models C and D are the same ISM hardware with a different operating RF power output level. Figures 14 - 21 are the graphic representation of the Clark tower data normalized at 1000 ft. range. All ISM equipment, except Model B, have RF field data for the equipment operating with RF shielding intact as per manufacturer's specifications in addition to data with specific RFI shielding removed. In all cases, the shielding is more effective at 27 MHz than at the fourth harmonic of the ISM operating frequency. In Figures 14 and 15 three sets of points are plotted corresponding to all RFI shields on, die table shields removed, and die table and oscillator shields removed. For these configurations some additional explanation is necessary. The device configured with shields removed refers to all RFI shielding surrounding the die table that have been removed along with the cosmetic metal panels surrounding the RF generation unit. The configuration described as "oscillator shields removed" indicates that all RFI shields surrounding the die table have been removed along with the metal closure walls of the master oscillator/power amplifier unit inside the RF power generating unit. In this configuration the cosmetic enclosure panels of the RF power generating unit are in place. This was done to simulate a configuration that might result from maintenance personnel not replacing all of the ISM device RFI shielding after performing maintenance on the unit.

As indicated in Figure 14, the ISM equipment is radiating less energy at 27 MHz with the oscillator shields removed than when all manufacturer's shields are in place. This indicates, to some extent, the differences in the ability of the ISM equipment to launch RF energy based on the device shielding configuration. Figure 15 indicates that at 108 MHz, having all shields in place except die table shields produces no real difference in launched RF energy, but the configuration with the oscillator shields removed has a substantial effect on the launched RF energy at 108 MHz. This is exactly the opposite with the same unit at 27 MHz, where the launched RF energy is lower with the oscillator shields removed than with all of the RFI shields in place.

The limited data of Figures 14 and 15 tend to indicate the presence of lobing in the vertical direction. This can be seen in the dip in the data of Figure 14 at about 60 degrees to the horizon. Also notice the rise in signal level above 60 degrees. This indicates that the unit under test may be radiating a lobe straight up above the unit. This same effect has been indicated in some of the airborne data plots. This tendency of the signal levels to increase for increasing elevation angles is present in all of the Clark tower measurements at both the fundamental and the 4th harmonic of the operating frequency. This vertical lobing effect is also indicated in the airborne measurements and is therefore not necessarily a function of the measurement procedures used for the Clark tower measurements.

Observed differences need to be pointed out regarding the measurement of two of the models with the Clark tower and airborne methods. First, the

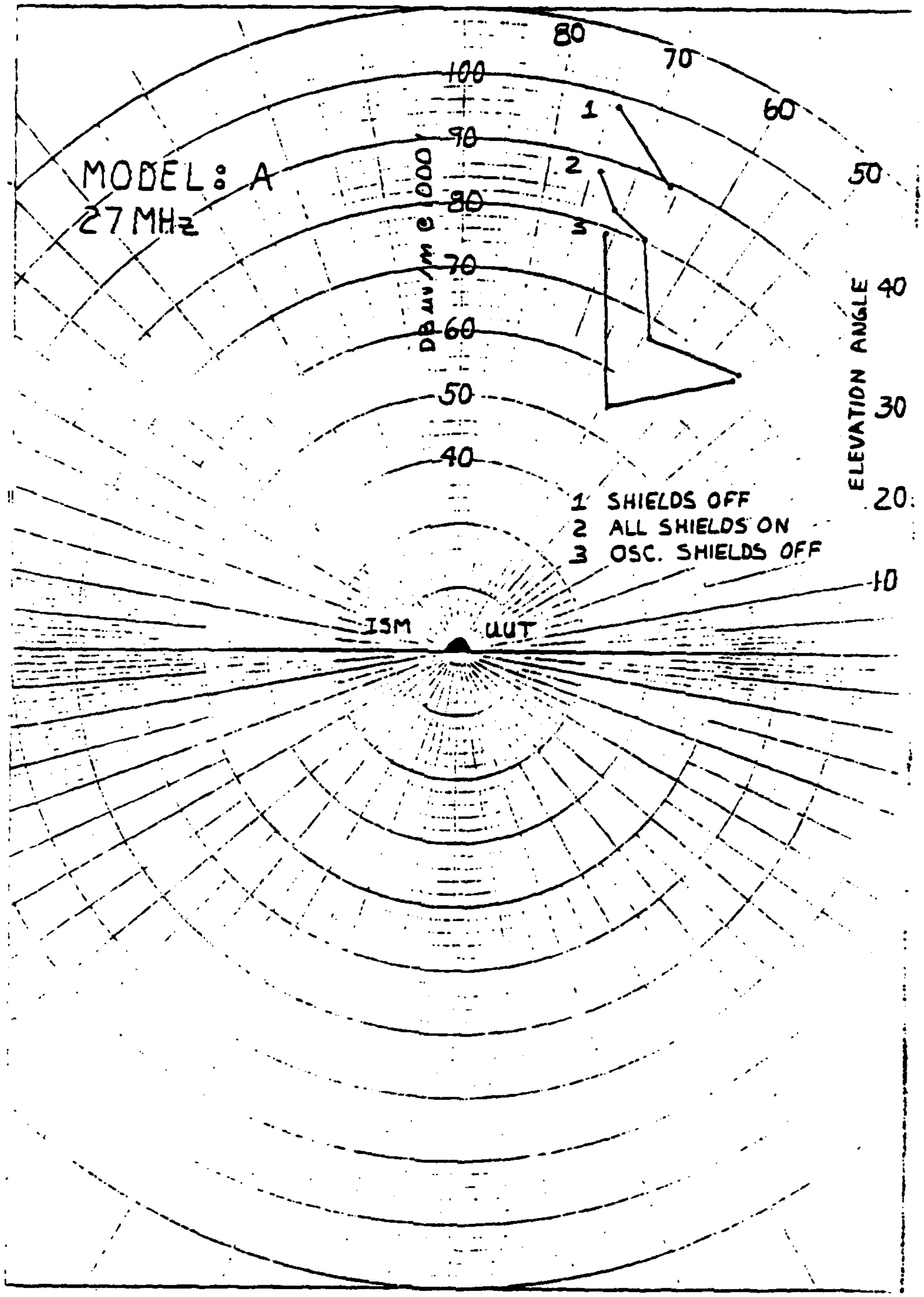


Figure 14. Fundamental Clark Tower Data for Model A, 25 kW, 180° Azimuth

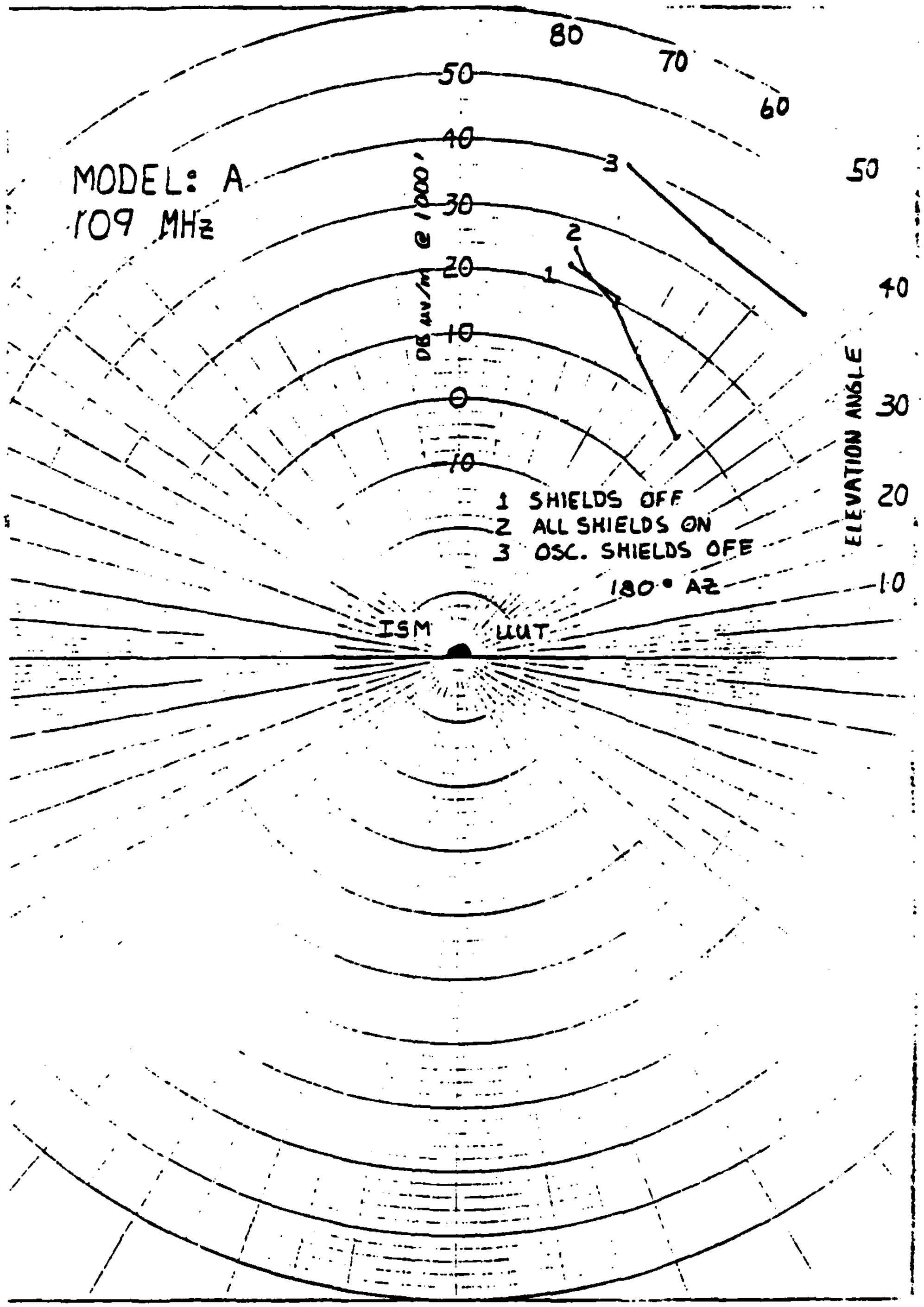


Figure 15. 4th Harmonic Clark Tower Data for Model A, 25 kW, 180° Azimuth

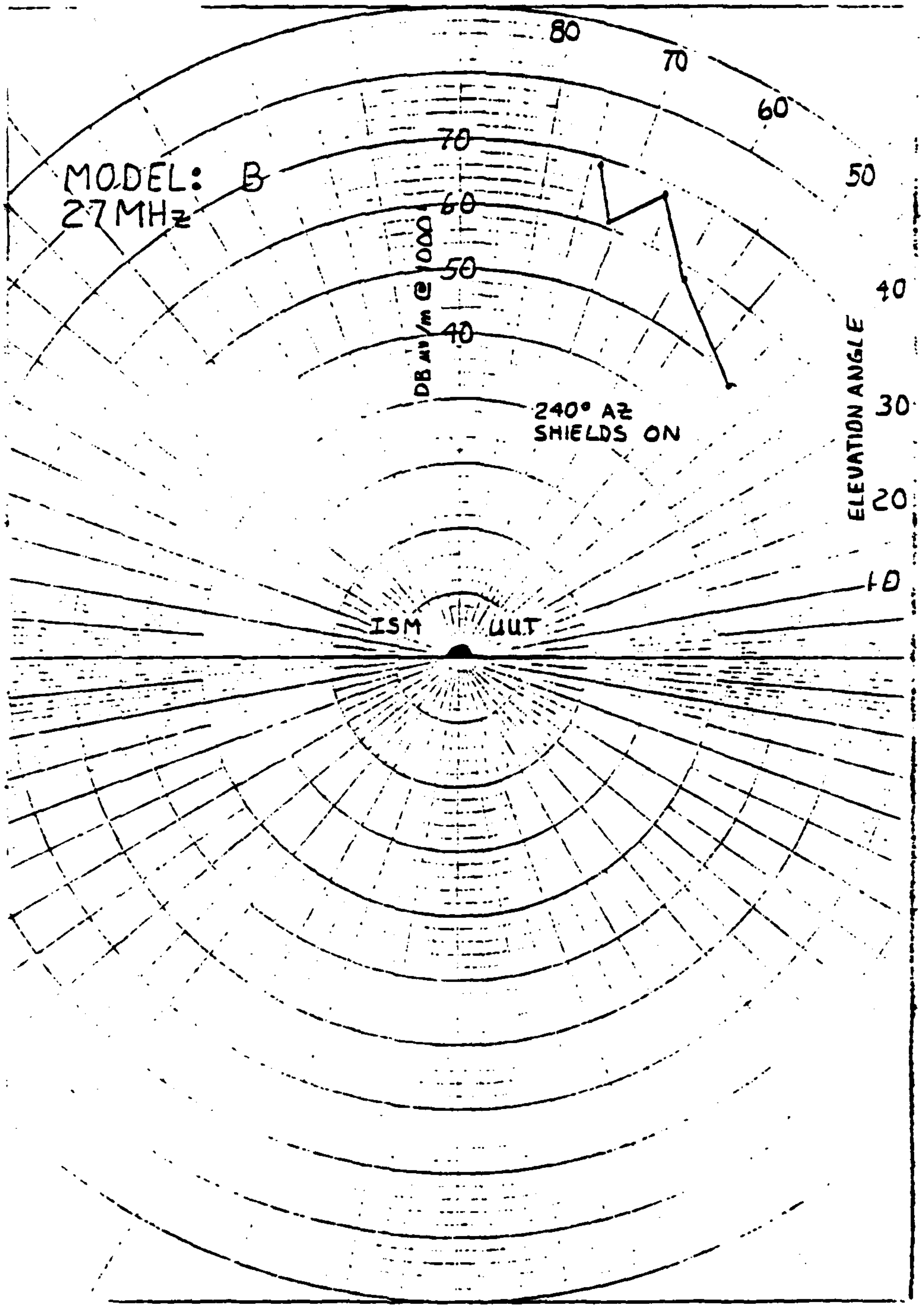


Figure 16. Fundamental Clark Tower Data for Model B, 2 kW, 240° Azimuth

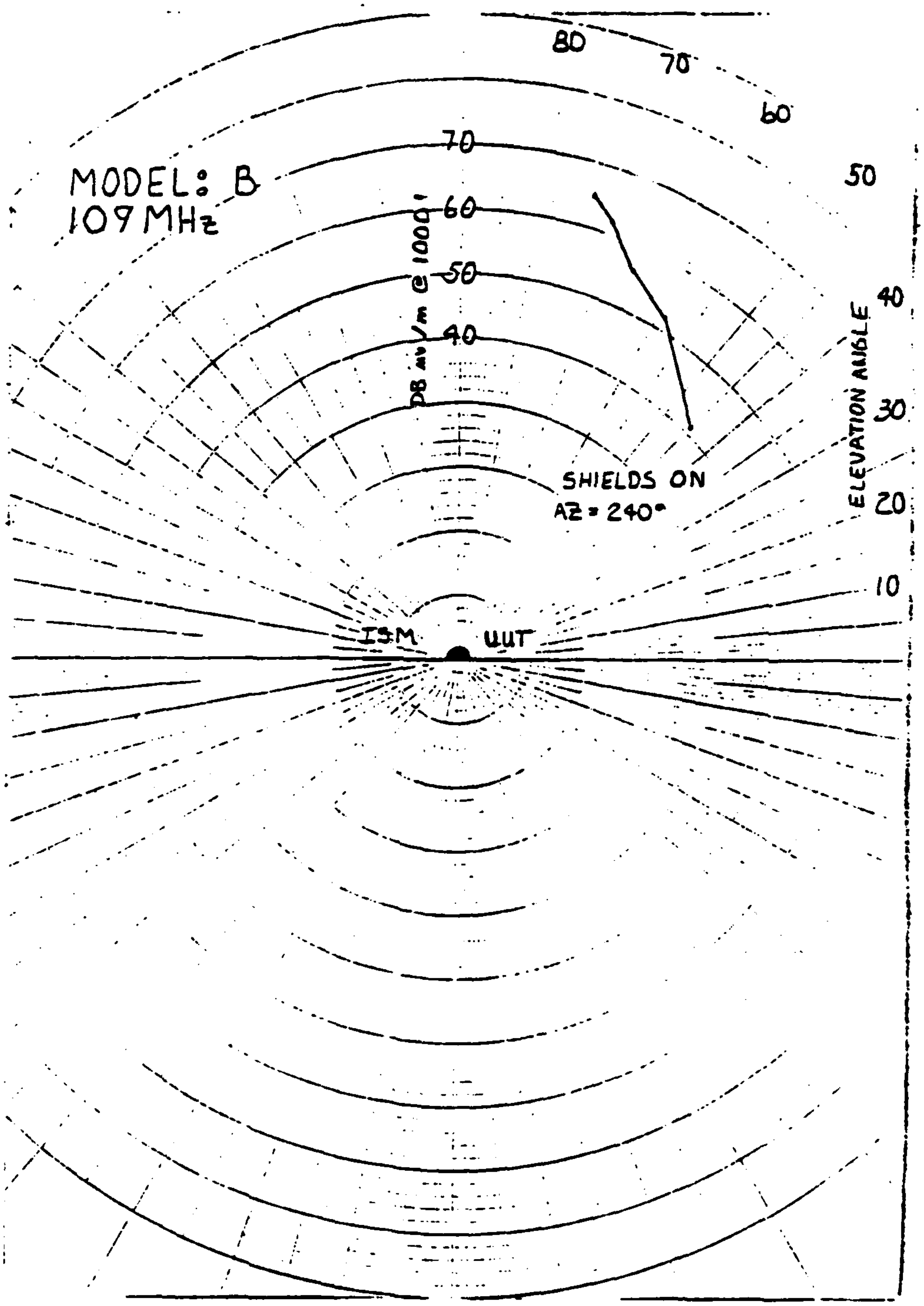


Figure 17. 4th Harmonic Clark Tower Data for Model B, 2 kW, 240° Azimuth

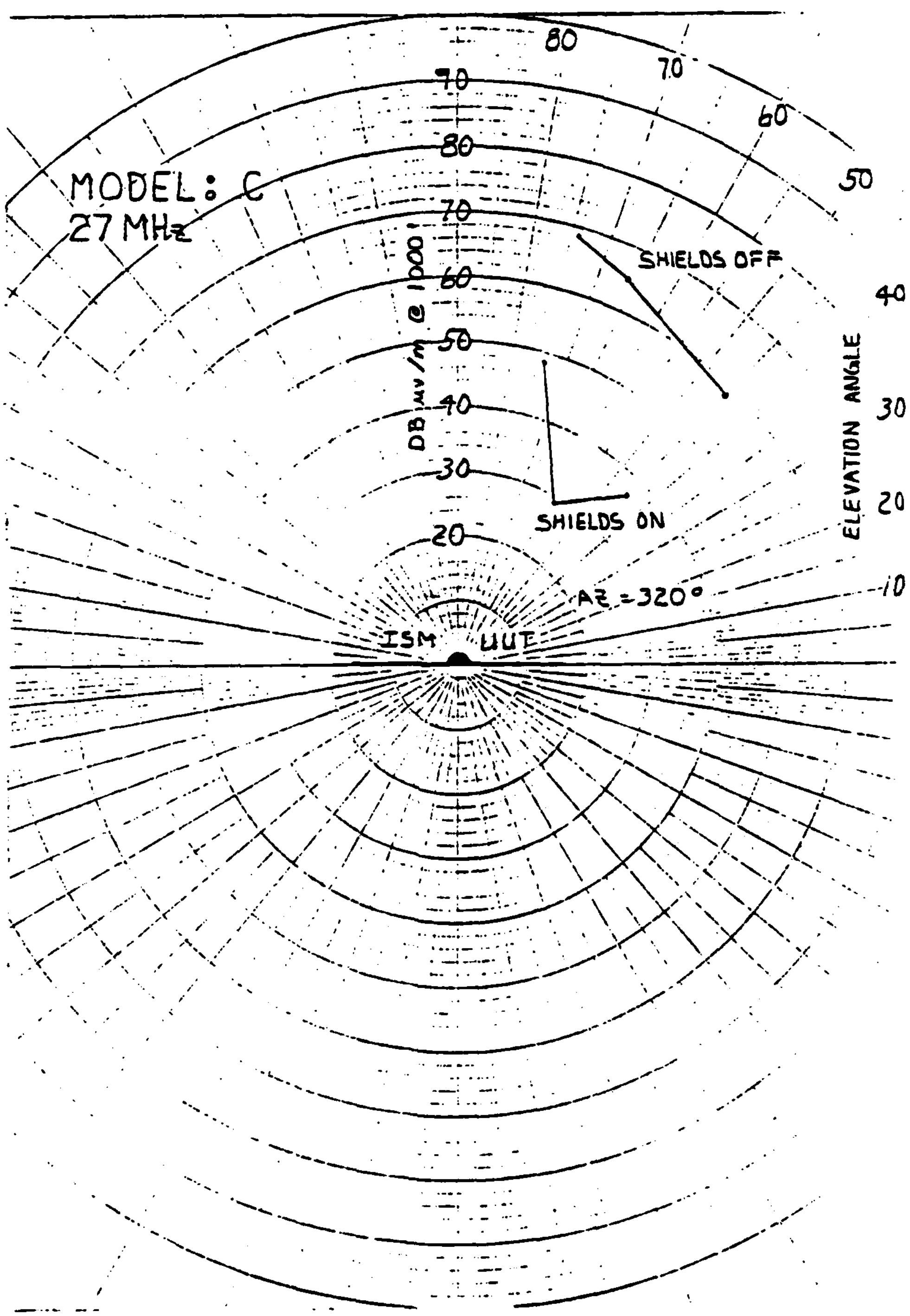


Figure 18. Fundamental Clark Tower Data for Model C, 3 kW, 320° Azimuth

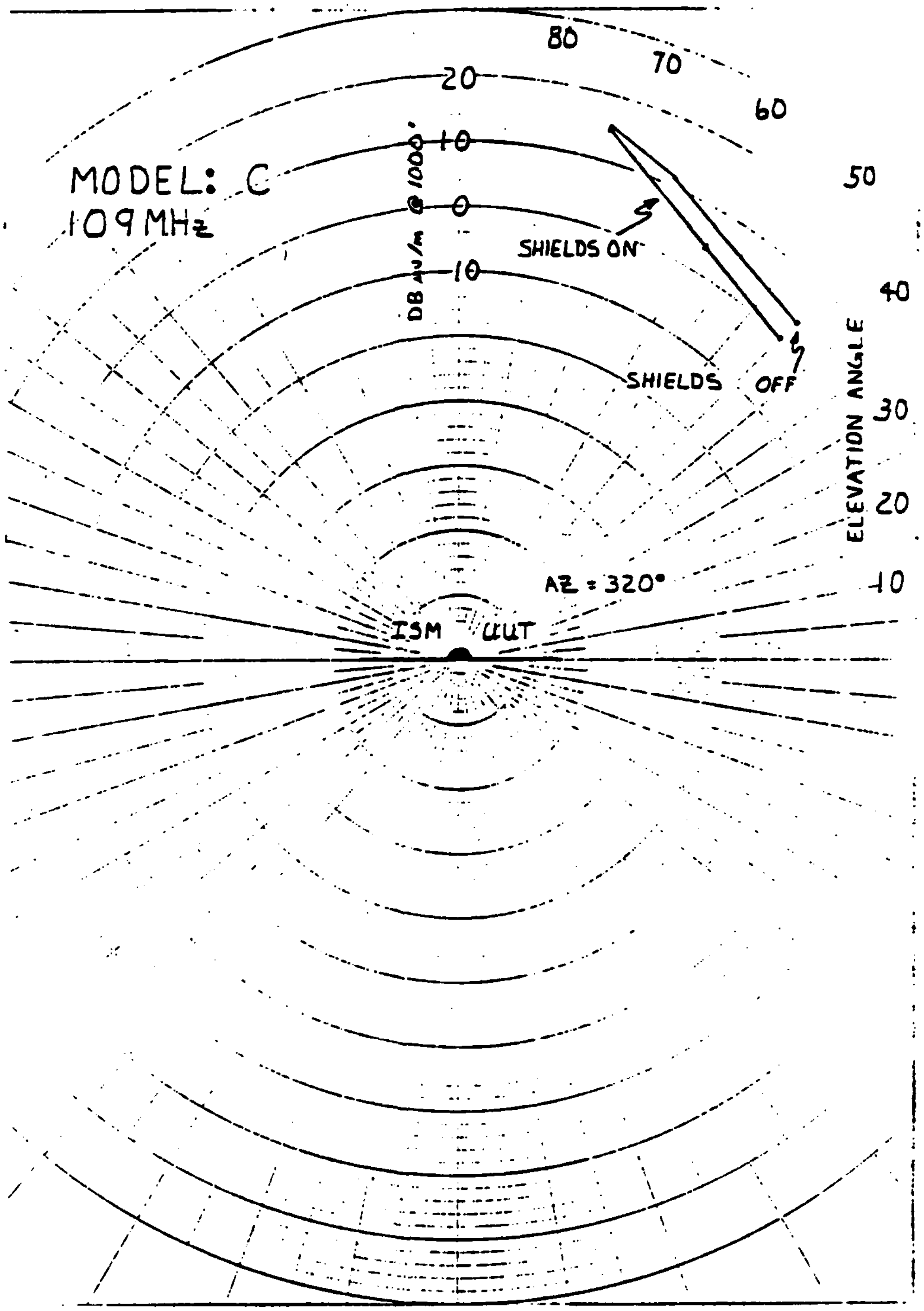


Figure 19. 4th Harmonic Clark Tower Data for Model C, 3 kW, 320° Azimuth

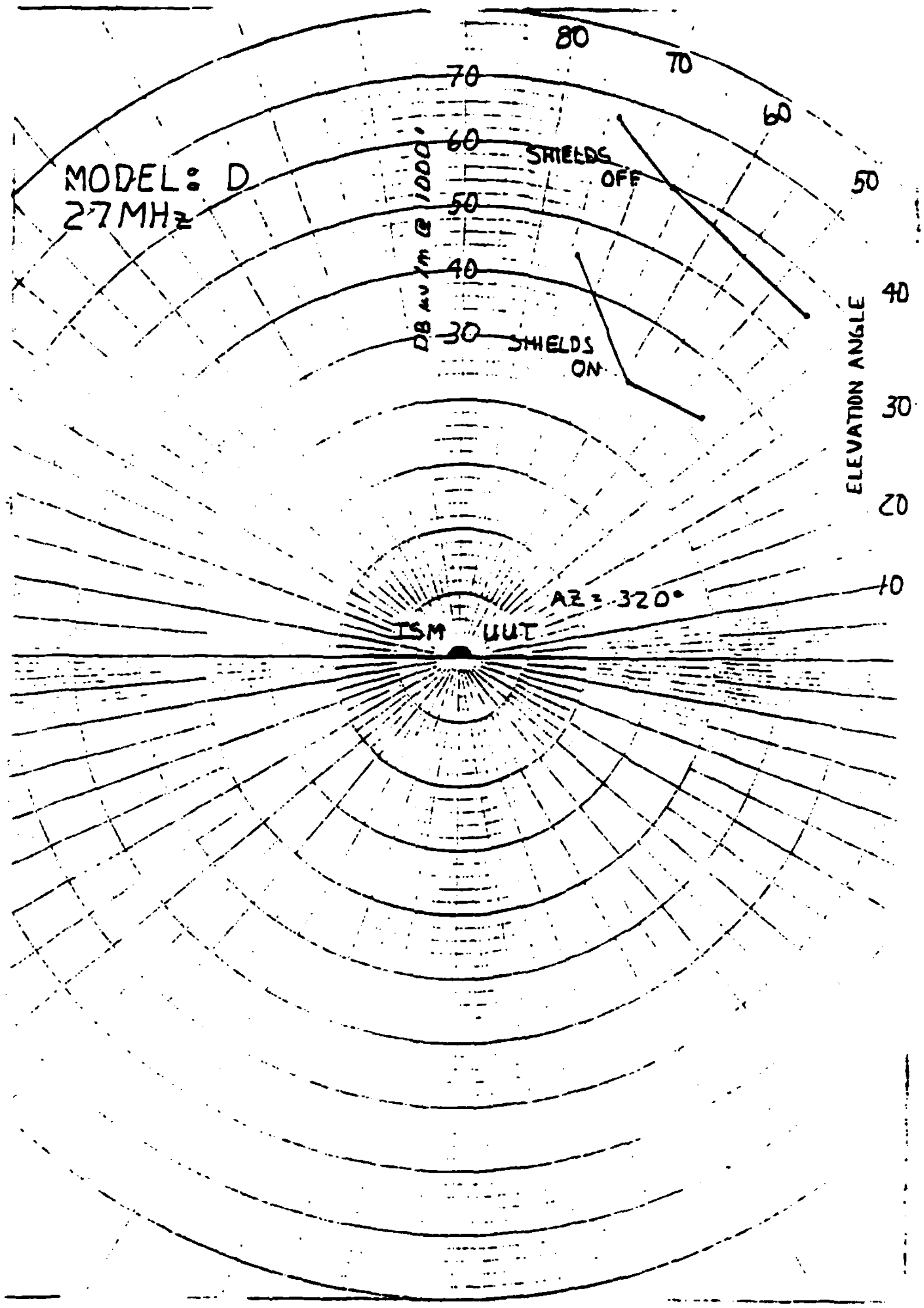


Figure 20. Fundamental Clark Tower Data for Model D, 2 kW, 320° Azimuth

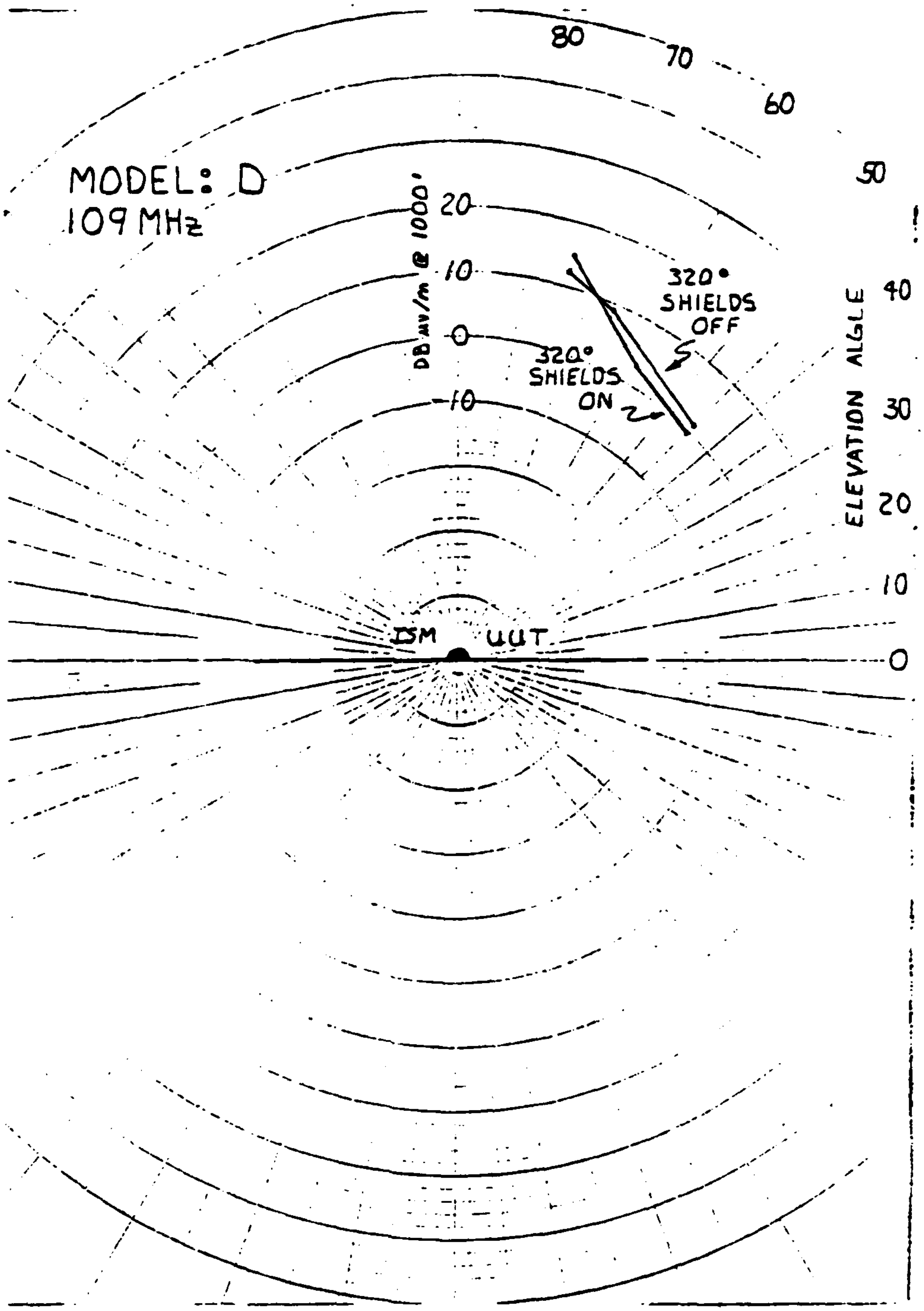


Figure 21. 4th Harmonic Clark Tower Data for Model D, 2 kW, 320° Azimuth

azimuth chosen for the Clark tower measurements for Model A was 180 degrees. This does not coincide with the ground-based lobe of maximum RF radiation. The maximum lobe from the ground-based test reported by Elite was 200 degrees. As indicated on the graphic data for the ISM device Model A, the Clark tower and airborne measurements were made at 180 degrees.

The second situation requiring clarification was that the measurements made on October 13, 1983, (for ISM device Model B for the Clark tower and the airborne measurements) do not reflect the same device tested at Waterman, Illinois. This is due to the fact that the 2 kW device, Model B, did not pass the FCC emissions limits for allowable field intensity at 1 mile. This unit was retested by Elite on November 11, 1983, with those results reported to Ohio University. The results are included in this report. The measured maximum lobe of radiation in the horizontal direction reported to Ohio University personnel on October 13, 1983, was 300 degrees, which is the azimuth used for the Clark tower and airborne measurements made by Ohio University on that date. For completeness of information the ISM device, Model B, did pass FCC testing performed by Elite on November 11, 1983. Tables 3 through 6 are the complete RF field intensities for the Clark tower measurements.

In spite of the foregoing exceptions, the quality and consistency of the testing indicate that these data do represent possible ranges of emission values obtainable from actual ISM equipment operation which was the goal of the study.

TABLE 3. TABLE OF DATA FOR MACHINE A CLARK TOWER MEASUREMENTS

CLARK TOWER MEASUREMENTS
MACHINE MODEL: A
OCT-12-1983

DECAY EXPONENT = 1.95

RF SHIELDS	ELEV ANG	AZIMUTH	dBμV 27MHz	dBμV(1000) 27MHz	dBμV 109MHz	dBμV(1000) 109MHz(1000)
ON	45.	180.	136.0	71.7	72.2	7.9
ON	59.	180.	126.0	66.8	73.3	14.1
ON	66.	180.	135.1	80.3	74.4	19.6
ON	71.	180.	134.4	83.2	73.3	22.1
ON	74.	180.	136.3	88.1	74.1	25.9
OFF	66.	180.	144.6	89.8	75.3	20.5
OFF	74.	180.	146.4	98.2	71.8	23.6
OSC OFF	71.	180.	129.9	78.7	91.7	40.5
OSC OFF	45.	180.	134.4	70.1	99.5	35.2
OSC OFF	59.	180.	114.4	55.2	94.2	35.0

TABLE 4. TABLE OF DATA FOR MACHINE B CLARK TOWER MEASUREMENTS

CLARK TOWER MEASUREMENTS
MACHINE MODEL: B
OCT-13-1983

DECAY EXPONENT = 1.57

RF SHIELDS	ELEV ANG	AZIMUTH	dBμV 27MHz	dBμV(1000) 27MHz	dBμV 109MHz	dBμV(1000) 109MHz(1000)
ON	45.	0.	118.4	66.6	93.9	42.1
ON	59.	0.	105.0	57.4	101.0	53.4
ON	66.	0.	109.2	65.1	102.7	58.6
ON	71.	0.	107.8	66.6	103.6	62.4
ON	74.	0.	110.6	71.8	104.5	65.7
ON	74.	300.	109.2	70.4	103.6	64.8
ON	74.	240.	107.6	68.8	104.1	65.3
ON	71.	240.	102.3	61.1	103.5	62.3
ON	71.	300.	111.7	70.5	103.0	61.8
ON	66.	300.	105.7	61.6	98.9	54.8
ON	66.	240.	112.4	68.3	100.6	56.5
ON	59.	240.	105.6	58.0	99.8	52.2
ON	59.	300.	104.3	56.7	100.6	53.0
ON	45.	300.	113.2	61.4	96.5	44.7
ON	45.	240.	101.1	49.3	92.7	40.9

TABLE 5. TABLE OF DATA FOR MACHINE C CLARK TOWER MEASUREMENTS

CLARK TOWER MEASUREMENTS
MACHINE MODEL: C
OCT-13-1983

DECAY EXPONENT = 1.95

RF SHIELDS	ELEV ANG	AZIMUTH	dBμV 27MHz	dBμV(1000) 27MHz	dBμV 109MHz	dBμV(1000) 109MHz(1000)
OFF	45.	320.	122.8	58.5	68.1	3.8
OFF	66.	320.	119.7	64.9	66.3	11.5
OFF	74.	320.	116.9	68.7	63.9	15.7
ON	74.	260.	100.5	52.3	57.4	9.2
ON	74.	320.	96.7	48.5	63.1	14.9
ON	74.	20.	96.4	48.2	66.5	18.3
ON	59.	20.	100.8	41.6	67.9	8.7
ON	59.	320.	88.3	29.1	63.5	4.3
ON	59.	260.	87.3	28.1	58.0	-1.2
ON	45.	260.	100.9	36.6	64.9	0.6
ON	45.	320.	101.9	37.6	64.3	-0.0
ON	45.	20.	109.4	45.1	65.5	1.2

TABLE 6. TABLE OF DATA FOR MACHINE D CLARK TOWER MEASUREMENTS

CLARK TOWER MEASUREMENTS
MACHINE MODEL: D
OCT-13-1983

DECAY EXPONENT = 1.95

RF SHIELDS	ELEV ANG	AZIMUTH	dBμV 27MHz	dBμV(1000) 27MHz	dBμV 109MHz	dBμV(1000) 109MHz(1000)
OFF	74.	320.	115.3	67.1	60.5	12.3
OFF	66.	320.	114.7	59.9	63.6	8.8
OFF	45.	320.	119.7	55.4	66.0	1.7
ON	45.	20.	105.0	40.7	64.4	0.1
ON	45.	320.	97.3	33.0	64.0	-0.3
ON	45.	260.	92.9	28.6	61.5	-2.8
ON	59.	260.	83.8	24.6	57.4	-1.8
ON	59.	320.	89.5	30.3	62.1	2.9
ON	59.	20.	97.5	38.3	64.7	5.5
ON	74.	20.	99.1	50.9	64.5	16.3
ON	74.	320.	93.1	44.9	62.6	14.4
ON	74.	260.	99.3	51.1	56.9	8.7

VII. CO-CHANNEL INTERFERENCE

The co-channel interference effects to ILS localizers from nonaviation RF radiation sources have been addressed in recent work completed by the International Civil Aviation Organization (ICAO) [5,6,7]. Additional work completed regarding co-channel interference effects on VOR signals from CATV is also pertinent, and indicates very similar desired-to-undesired signal criteria to provide interference protection to localizers [8].

ICAO has defined four types of co-channel signals. Three of these types deal with unmodulated signals, and the remaining type involves modulated signals. In all cases, the specified desired/undesired (D/U) signal levels indicate interference that will cause no more than 5μa of localizer course deviation. The four types of interfering signals referred to by ICAO are summarized below.

Unmodulated Carrier Interference:

TYPE I An unmodulated carrier within the localizer receiver RF passband and within 0.5 Hz of the 90 or 150 Hz sideband modulation of the ILS localizer must be as low as 46 dB below the desired localizer carrier.

TYPE II An unmodulated carrier within the localizer receiver RF passband and within 10 Hz of the 90 or 150 Hz sidebands, but not within the TYPE I tolerance, must be as low as 26 dB below the desired localizer carrier.

TYPE III An unmodulated carrier except TYPE I and TYPE II within the localizer receiver RF passband with sufficient strength will cause progressive capturing of the receiver. The unwanted RF signal field strength must be as low as 7 dB below the desired localizer carrier level.

Modulated Carrier Interference:

TYPE IV An unwanted carrier except TYPE I and TYPE II with 20% amplitude modulation by either 90 or 150 Hz components must be as low as 13 dB below the desired localizer carrier level.

In general, any of the first three types are possible as interference to localizers from ISM equipment. The equipment tested during the contract produced only CW emissions.

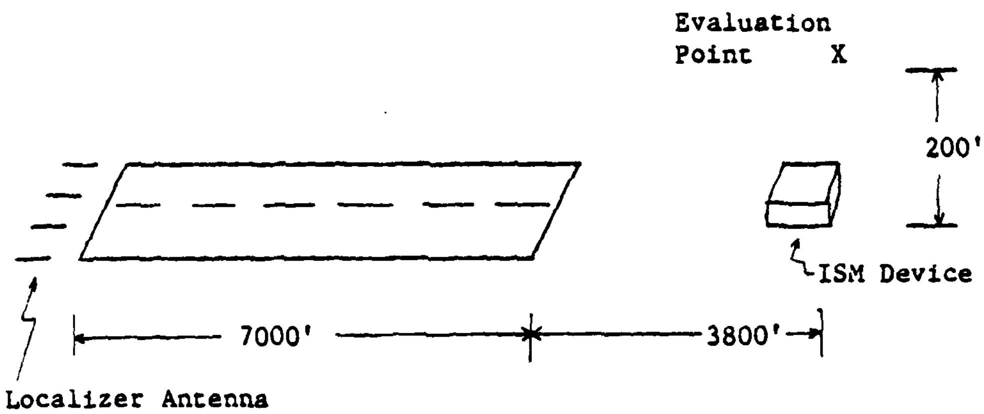
To correlate the findings of this report to co-channel interference, a worst case example will be considered. The example is based on placing the ISM equipment at a point below a localizer approach course, located 3800 feet from the threshold of the runway and 200 feet below the glide path. A runway length of 7000 feet is assumed, with the ISM device producing co-

channel interference at the FCC or CISPR emissions limits. Table 7 indicates whether the ICAO D/U signal level criteria is satisfied. The conditions for the comparison are included in the table. Measurements were made of the RF field strength of a localizer operating at the Ohio University Airport with a value of 91 dBμV/m measured at the point in the approach indicated above. This signal level is significantly higher than the level considered as a minimum in ICAO Annex 10, Volume I, Part I, of 46 dBμV/m [9] at the threshold.

The results indicated in Table 7 represent the readings from the open field measurements performed at Waterman, Illinois; the airborne measured RF fields are generally 20 to 40 dB above those measured on the ground. These results indicate that CISPR emissions limits do provide sufficient D/U levels except for the signal levels measured in the airborne tests considering TYPE I interference. For FCC emissions limits the results are quite different. All but one of the measured conditions fail the criteria for D/U signal levels. The one condition that did exceed the D/U level was for the TYPE III interference.

TABLE 7. PASS FAIL FOR ICAO INTERFERENCE DESIRED-TO-UNDESIRED SIGNAL CRITERIA EXAMPLE

	GROUND TESTS		AIRBORNE TESTS	
	CISPR	FCC	CISPR	FCC
TYPE I	yes	no	no	no
TYPE II	yes	no	yes	no
TYPE III	yes	yes	yes	no



VIII. ACKNOWLEDGMENTS

The authors would like to thank the following persons for their efforts: Dr. Robert Lilley for his skill as the pilot of the aircraft during the long hours of the flight tests in Waterman, Illinois; Mr. Richard Zoulek who completed the mechanical details of the flight instrumentation package and the preparation of the Clark tower; and Mr. James Klouda and Mr. John Modica for their work at the test site in Waterman, Illinois. We all worked long hours to complete the tests on time. Finally, I would like to thank Mr. Robert Smith of the FAA for his efforts in speeding up the necessary paper work required by the contract.

IX. REFERENCES

[1] Kraus, J.D., "Antennas," McGraw-Hill Book Company, Inc., 1950, p. 308.

[2] Federal Communications Commission, Rules and Regulations, Volume II, Part 18, Industrial, Scientific and Medical Equipment, July 1981.

[3] International Electrotechnical Commission, International Special Committee on Radio Interference C.I.S.P.R., Publication 11, 1975.

[4] International Electrotechnical Commission, International Special Committee on Radio Interference C.I.S.P.R., Publication 11A, 1976.

[5] ICAO Agenda Item 9: Development of Standards, Recommended Practices and Guidance Material Relating to Harmful Interference in the Aeronautical Radio Bands. COM/81-WP/105, August 1981.

[6] ICAO Agenda Item 9: Development of Standards, Recommended Practices and Guidance Material Relating to Harmful Interference in the Aeronautical Radio Bands. COM/81-WP/31, March 1981.

[7] ICAO Agenda Item 9: Development of Standards, Recommended Practices and Guidance Material Relating to Harmful Interference in the Aeronautical Radio Bands. COM/81-WP/30, March 1981.

[8] Jurushek, J.R., T. Marr, "Flight Tests Measuring Compatibility of Simulated CATV and VOR Signals," Office of Telecommunications, Institute for Telecommunications Sciences, DOT-FA74WAI-467, Oct. 1975.

[9] ICAO Aeronautical Telecommunications Annex 10 to the Convention on International Civil Aviation, International Standards and Recommended Practices, Volume I, July, 1972.

X. APPENDIXES

Appendix A.

This appendix contains all flight measurement plots for the open field testing of the four ISM devices tested at Waterman, Illinois. These are the plots of absolute field strength in dBμV/m vs. horizontal position of the aircraft over the ground. The plots have superimposed on them the RF radiation limits for FCC and CISPR for easy interpretation of the data relative to these limits. All distances are expressed in meters. These plots are referred to in the text of the report.

AIRBORNE PLOTS - MACHINE A

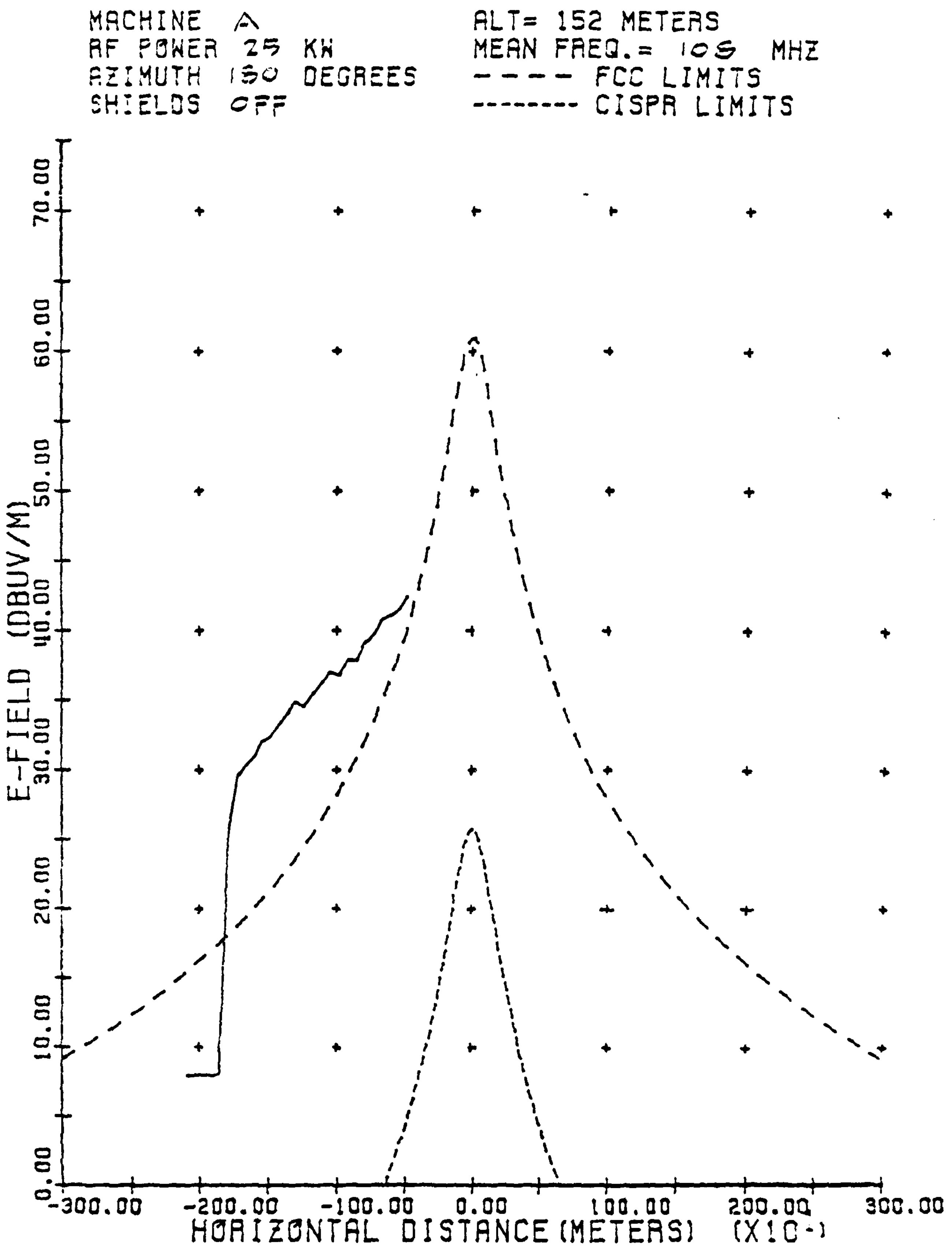


Figure A-1. Flight Data Machine A, 25 kW, 152 M Altitude, 180° Azimuth, RFI Shields Removed

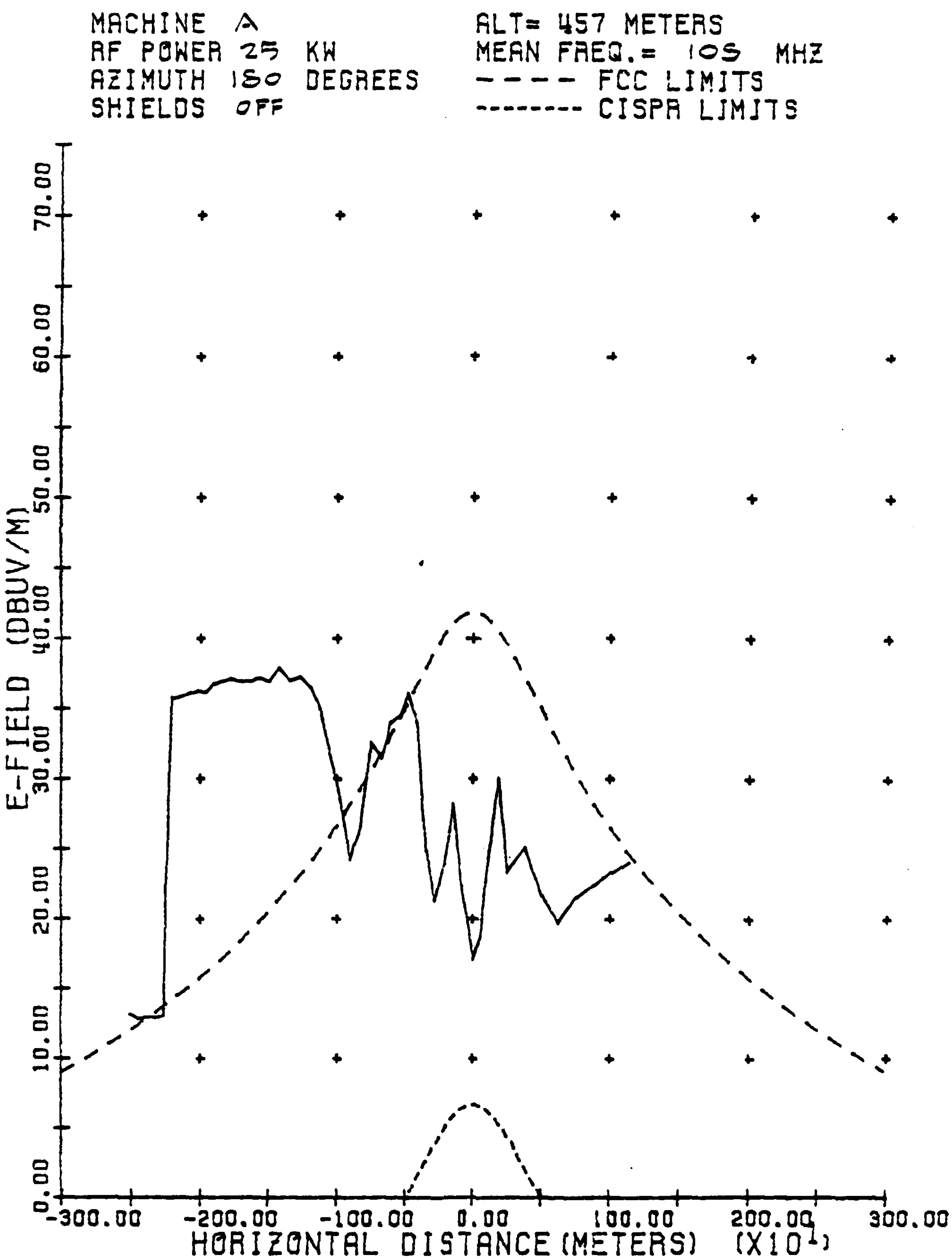


Figure A-2. Flight Data Machine A, 25kW, 457 M Altitude, 180° Azimuth, RFI Shields Removed

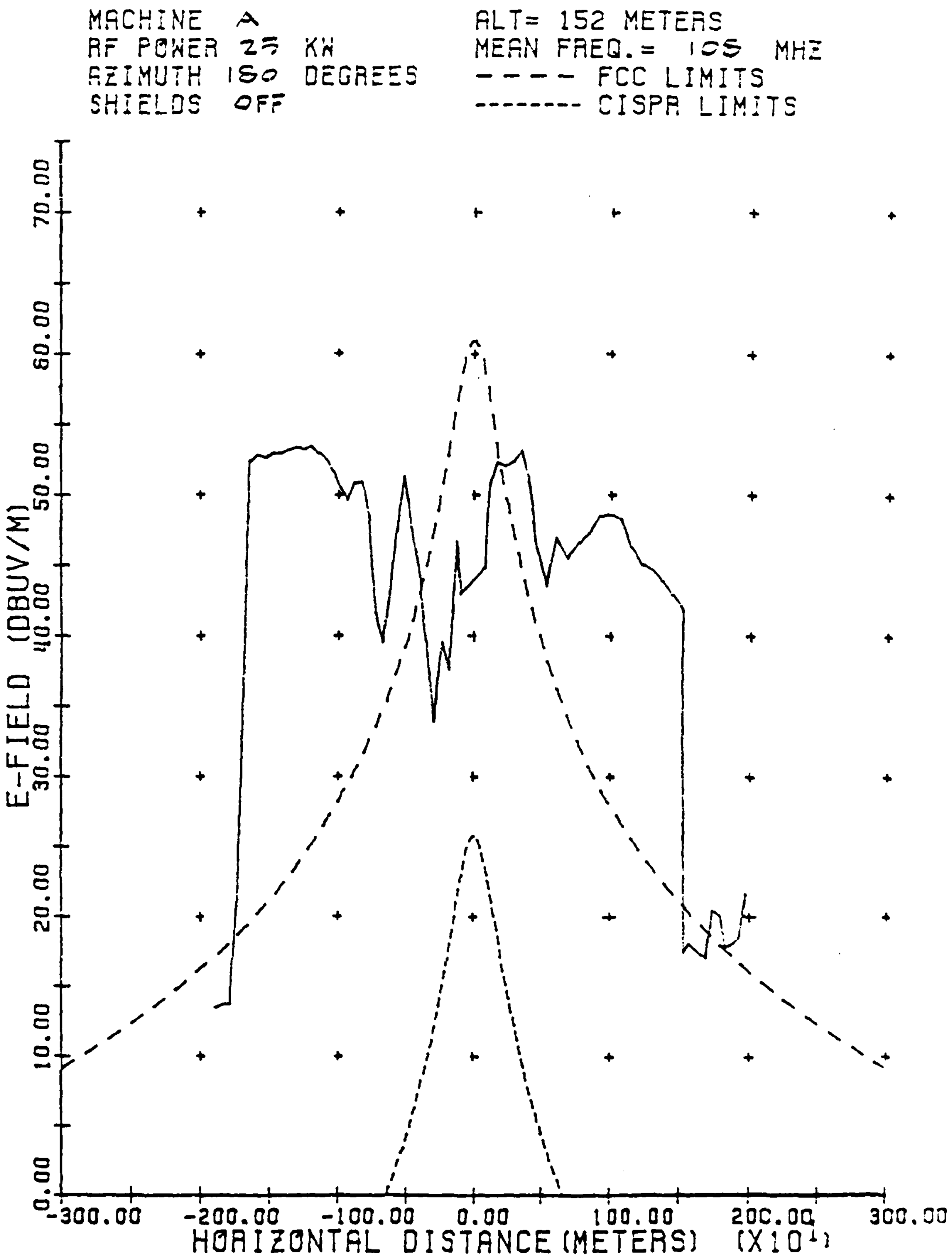


Figure A-3. Flight Data Machine A, 25kW, 152 M Altitude, 180° Azimuth, RFI Shields Removed

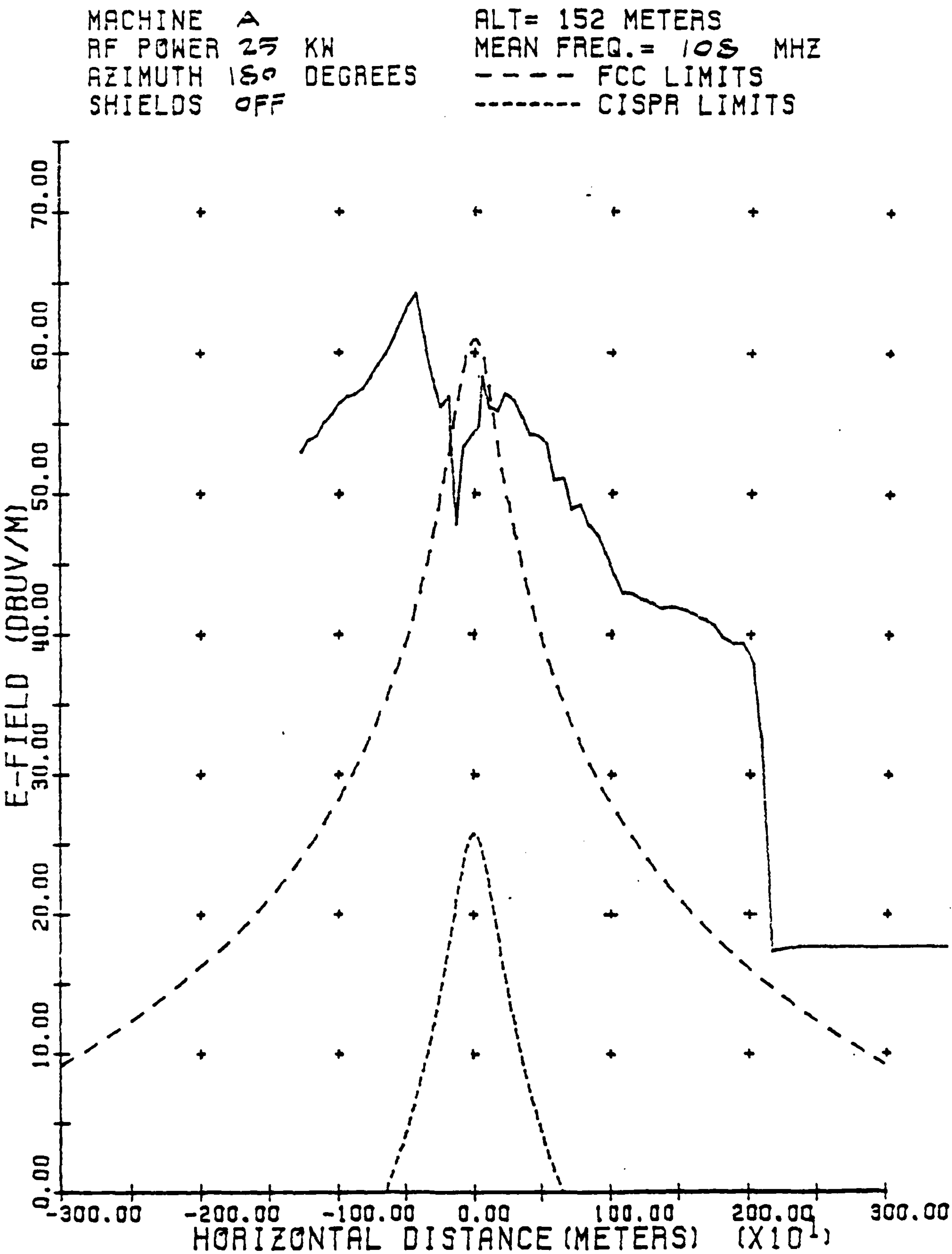


Figure A-4. Flight Data Machine A, 25 kW, 152 M Altitude, 180° Azimuth, RFI Shields Removed

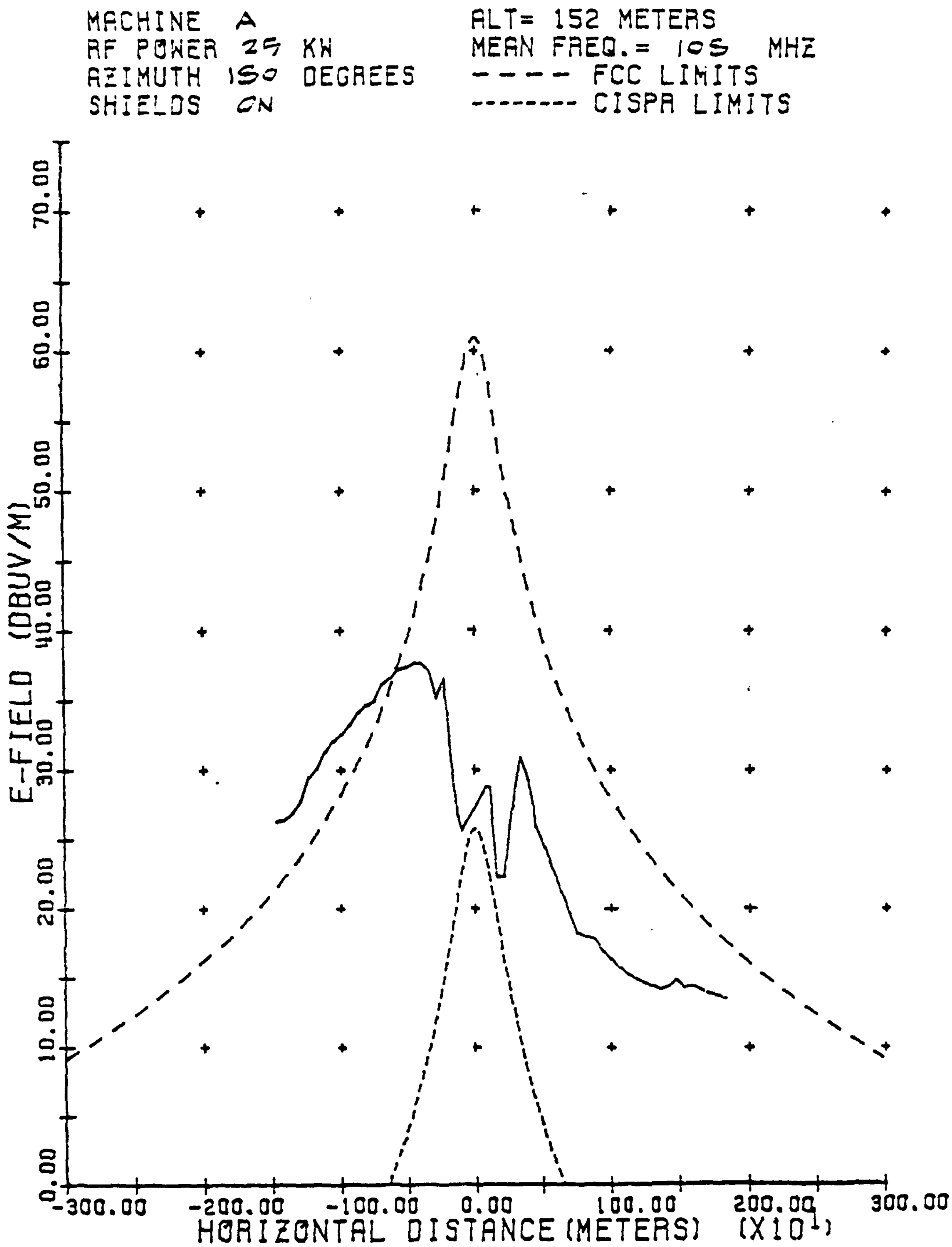


Figure A-5. Flight Data Machine A, 25kW, 152 M Altitude, 180° Azimuth, RFI Shields in Place

AIRBORNE PLOTS - MACHINE B

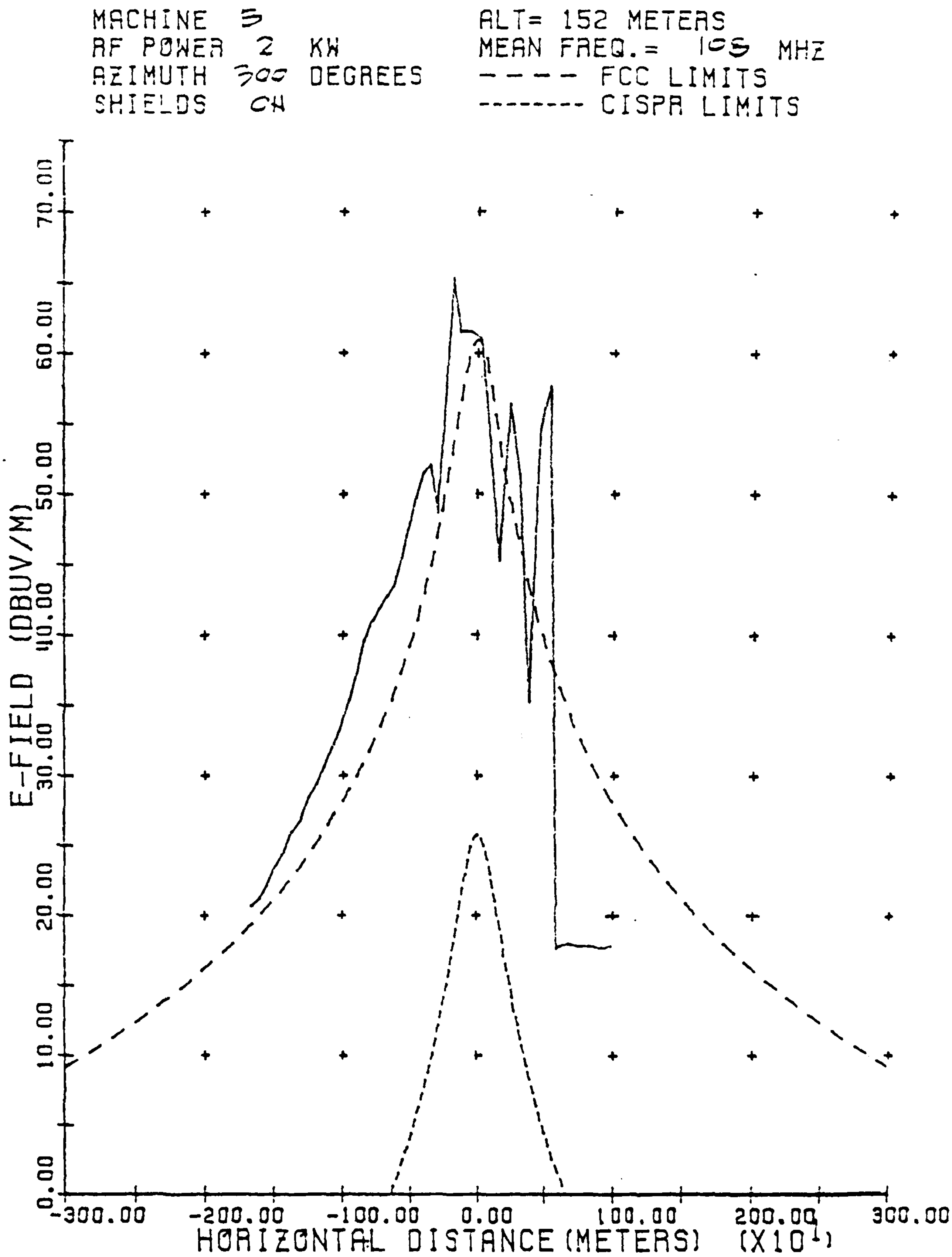


Figure A-6. Flight Data Machine B, 2 kW, 152 M Altitude, 300° Azimuth, RFI Shields In Place

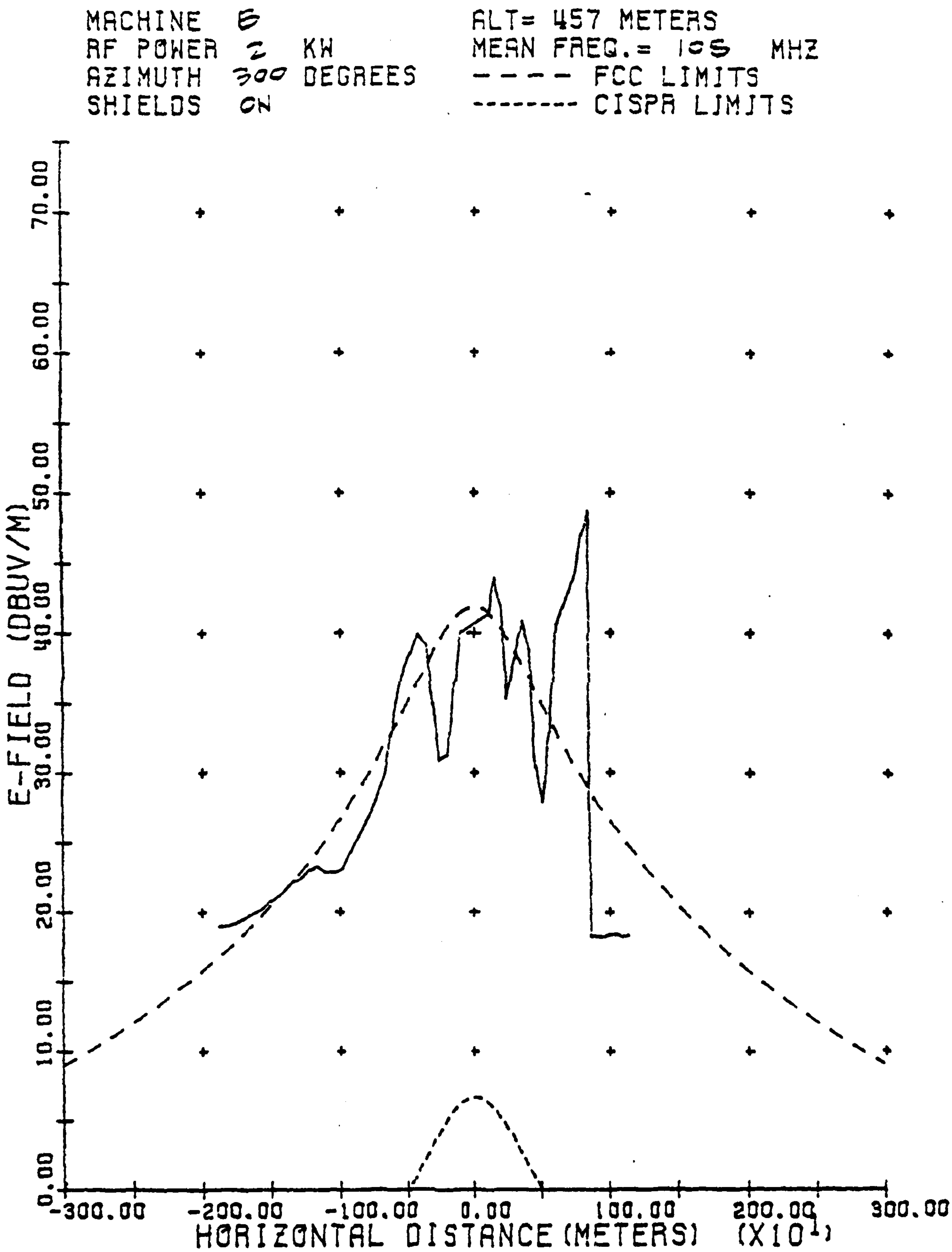


Figure A-7. Flight Data Machine B, 2 kW, 457 M Altitude, 300° Azimuth, RFI Shields In Place

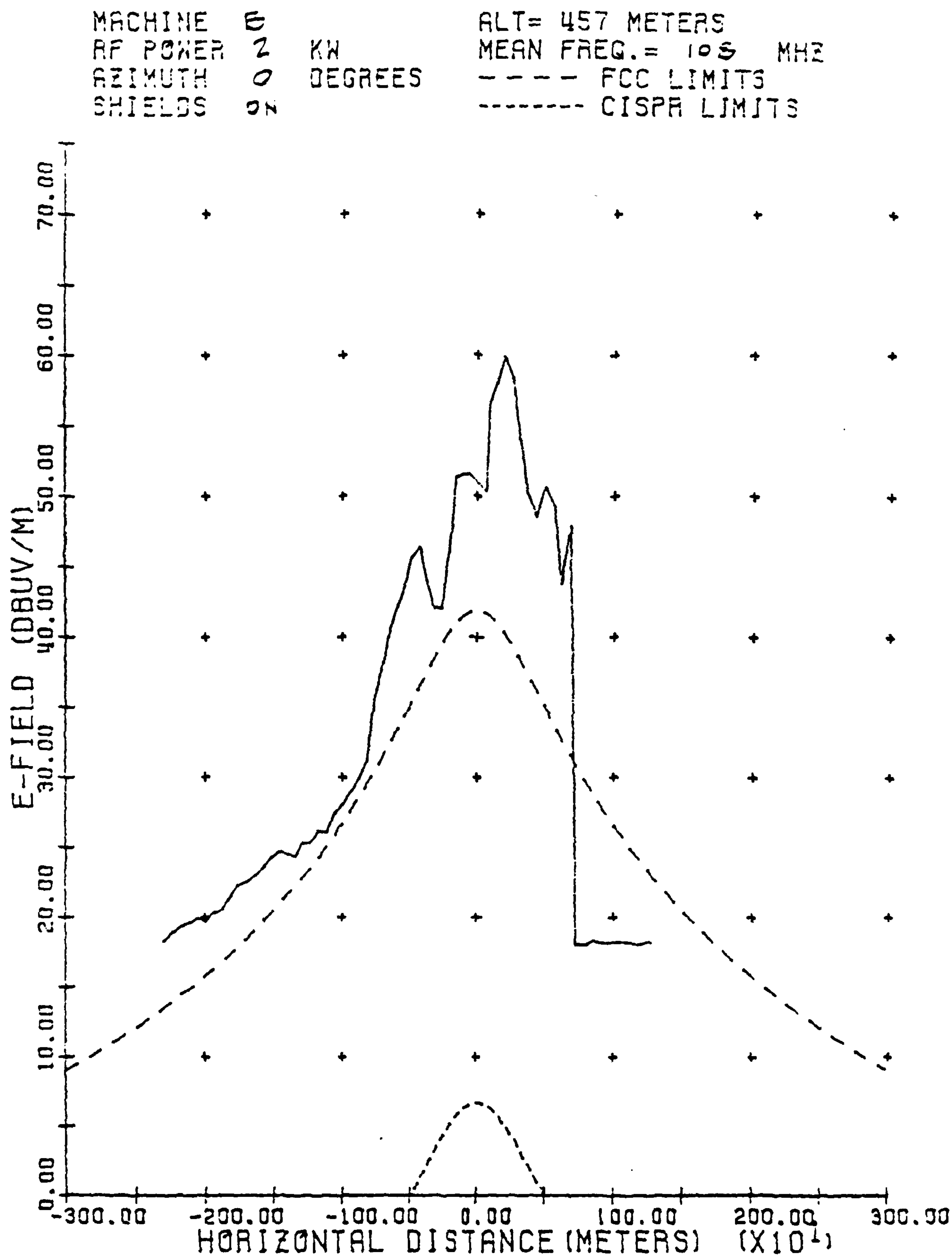


Figure A-8. Flight Data Machine B, 2 kW, 457 M Altitude, 0° Azimuth, RFI Shields In Place

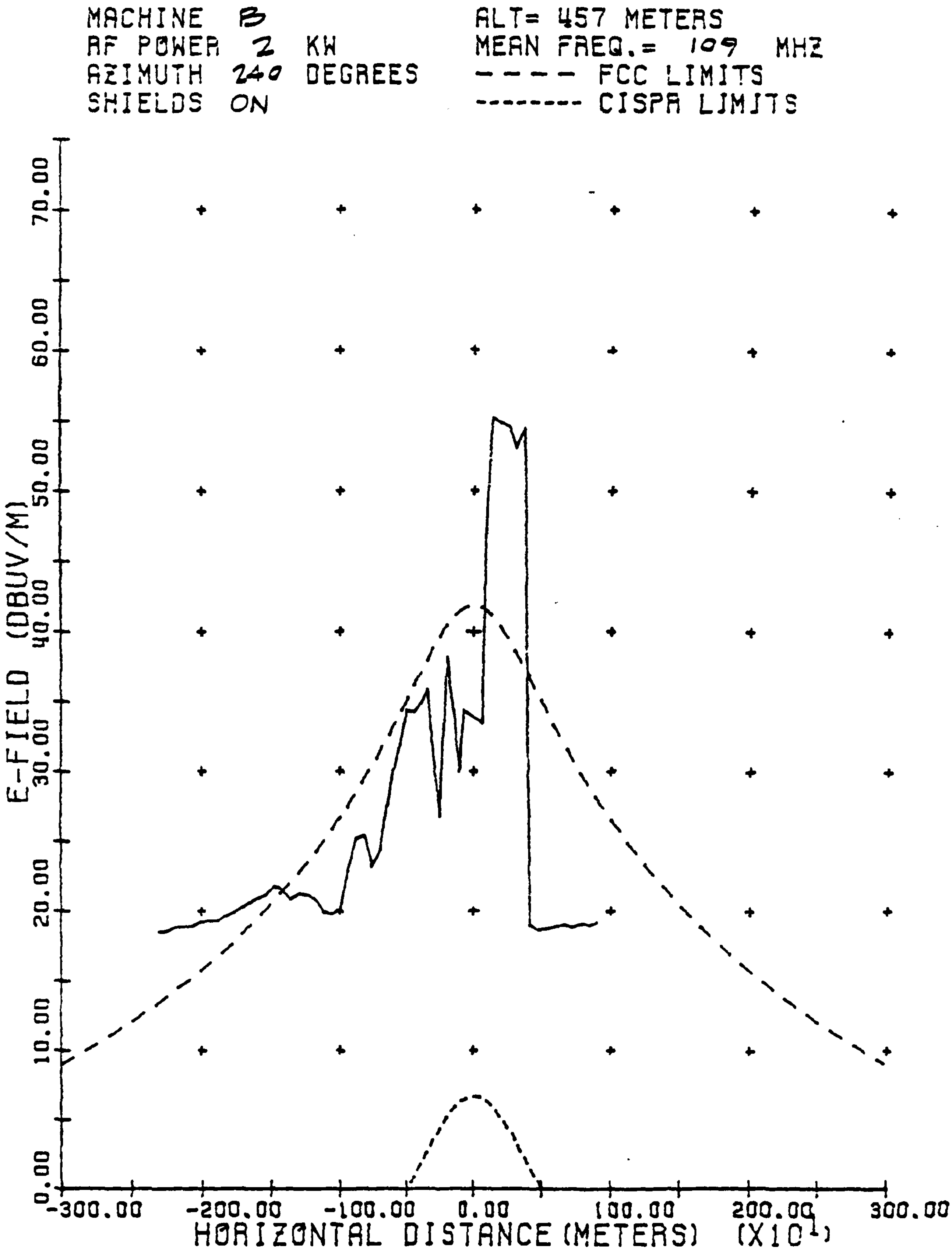


Figure A-9. Flight Data Machine B, 2kW, 457 M Altitude, 240° Azimuth, RFI Shields In Place

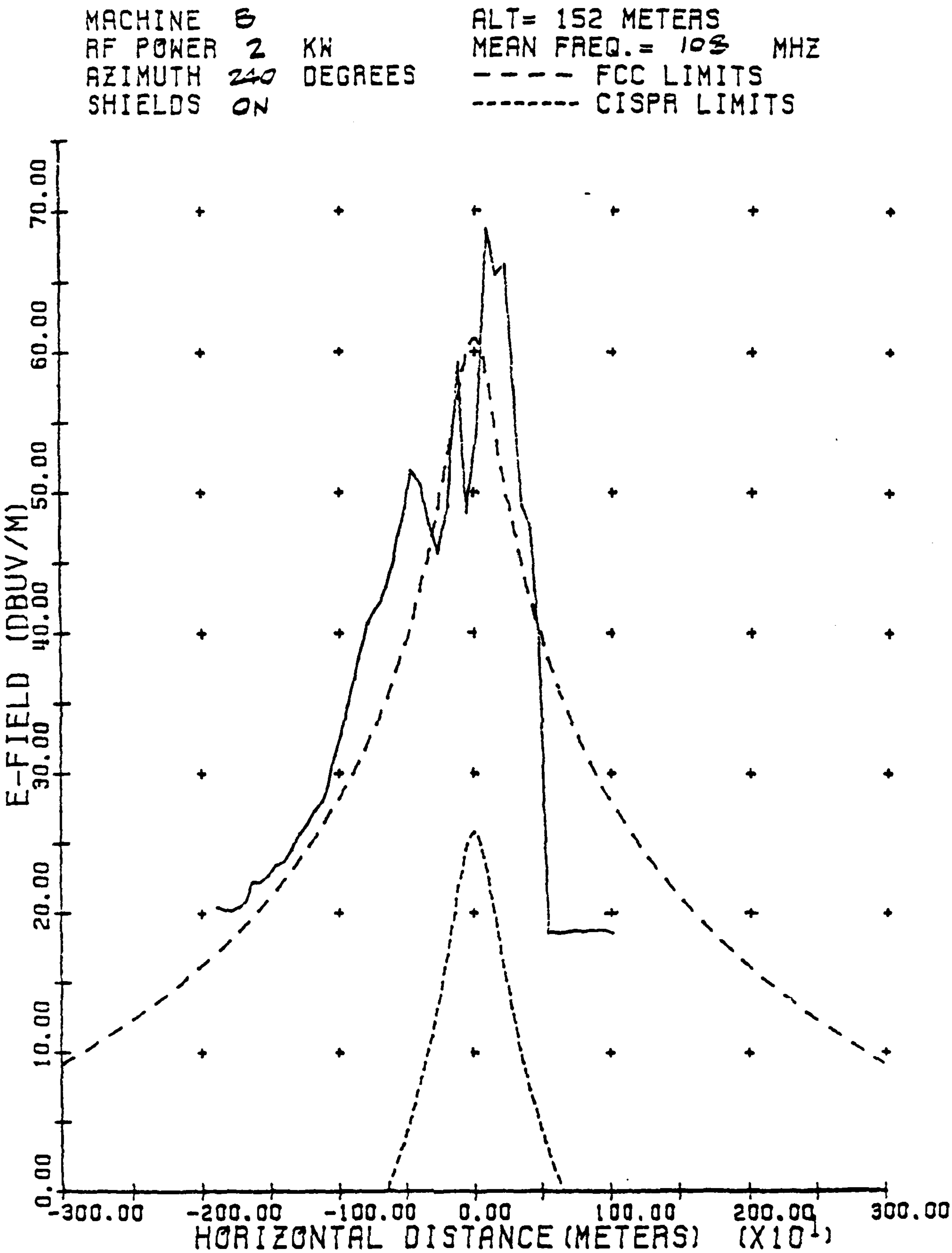


Figure A-10. Flight Data Machine B, 2 kW, 152 M Altitude, 240° Azimuth, RFI Shields In Place

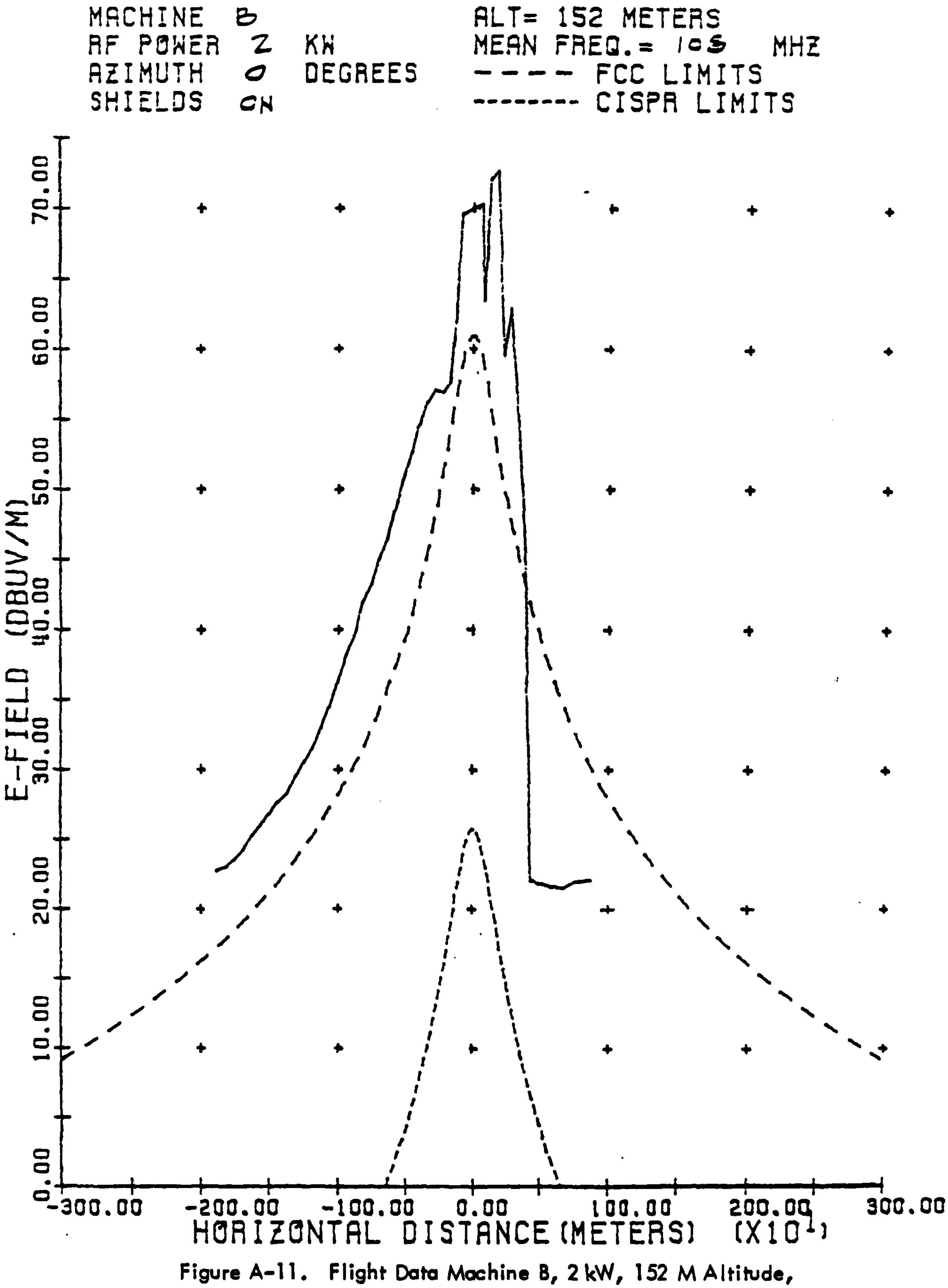


Figure A-11. Flight Data Machine B, 2 kW, 152 M Altitude, 0° Azimuth, RFI Shields In Place

AIRBORNE PLOTS - MACHINE C

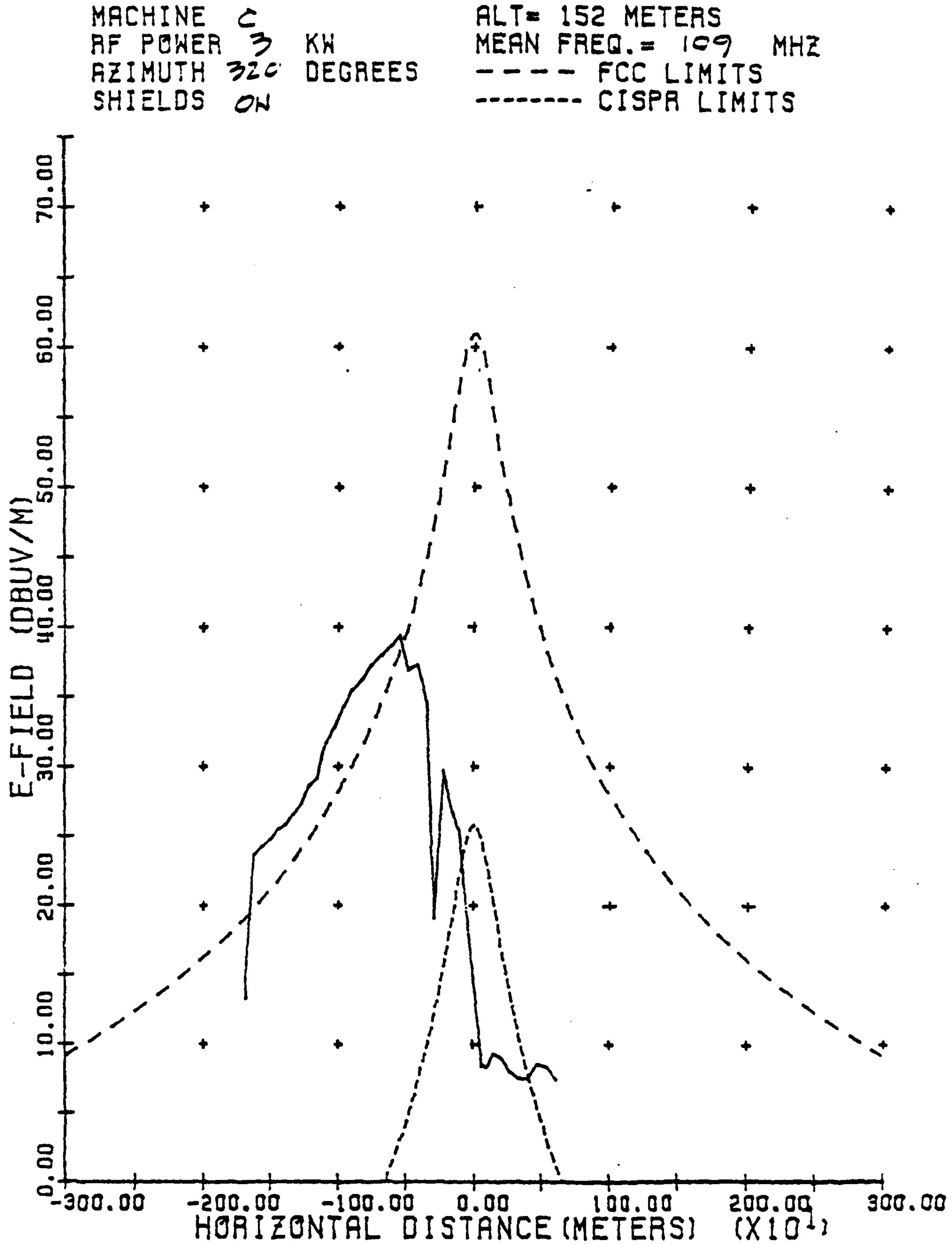


Figure A-12. Flight Data Machine C, 3kW, 152 M Altitude, 320° Azimuth, RFI Shields In Place

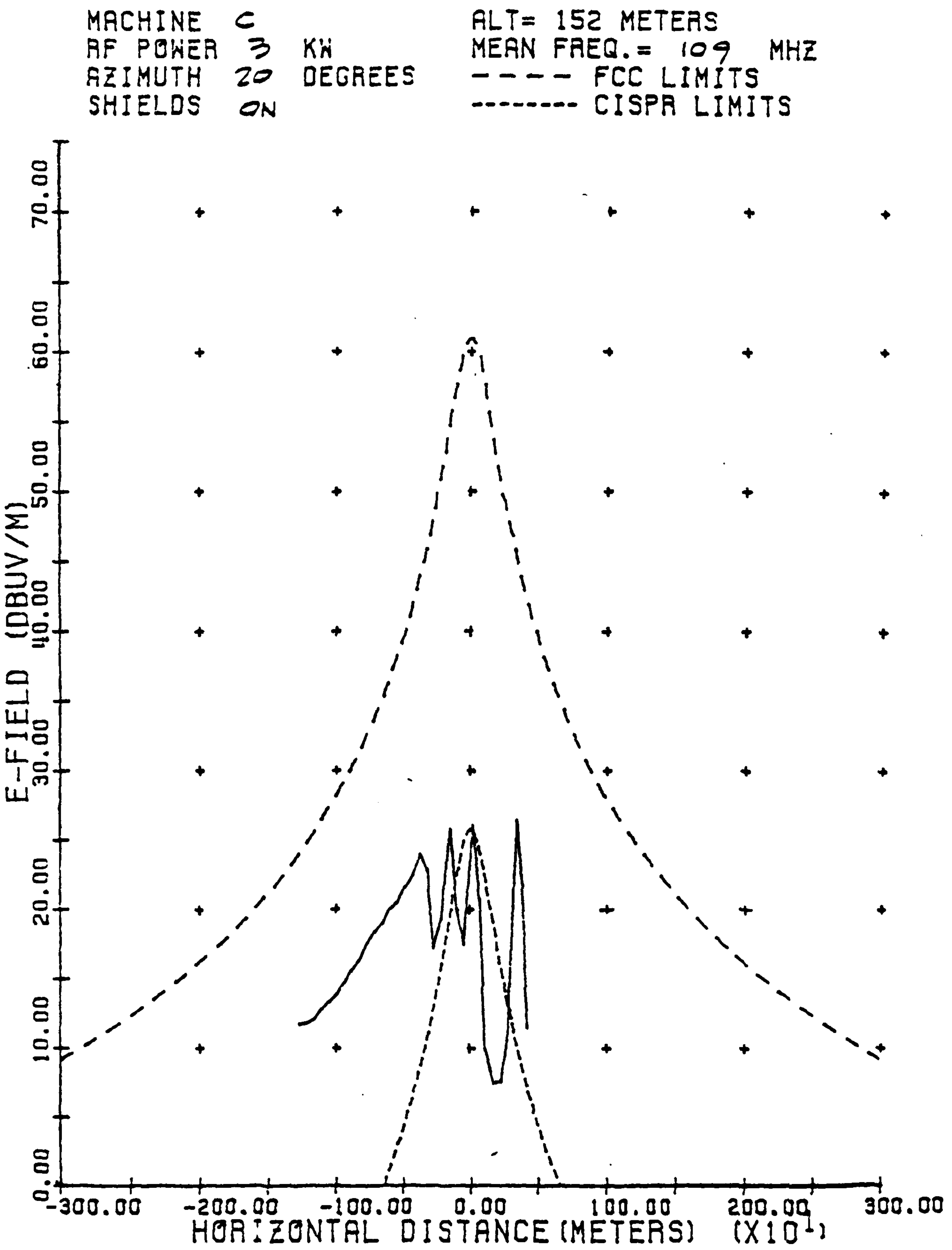


Figure A-13. Flight Data Machine C, 3 kW, 152 M Altitude, 20° Azimuth, RFI Shields In Place

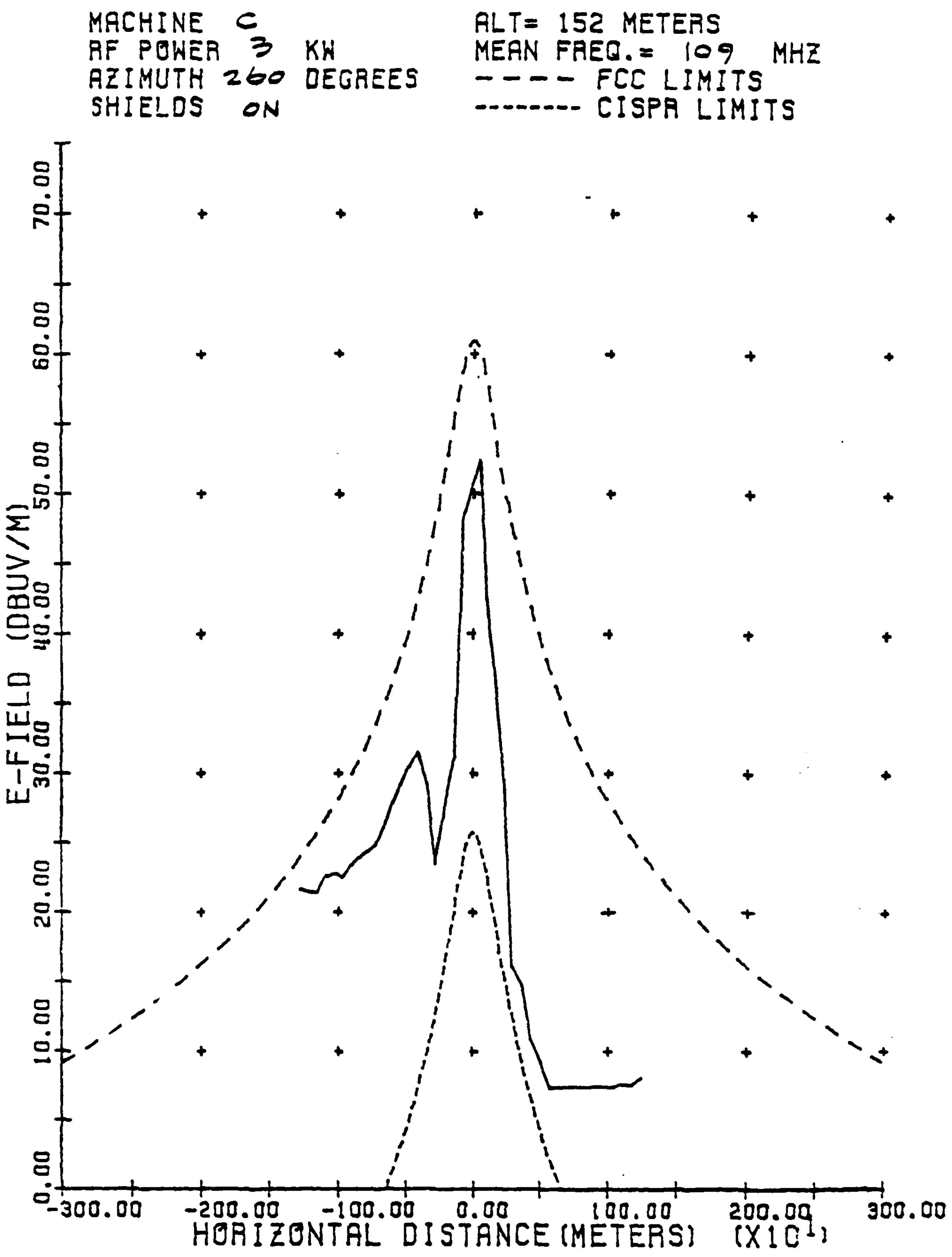


Figure A-14. Flight Data Machine C, 3kW, 152 M Altitude, 260° Azimuth RFI Shields In Place

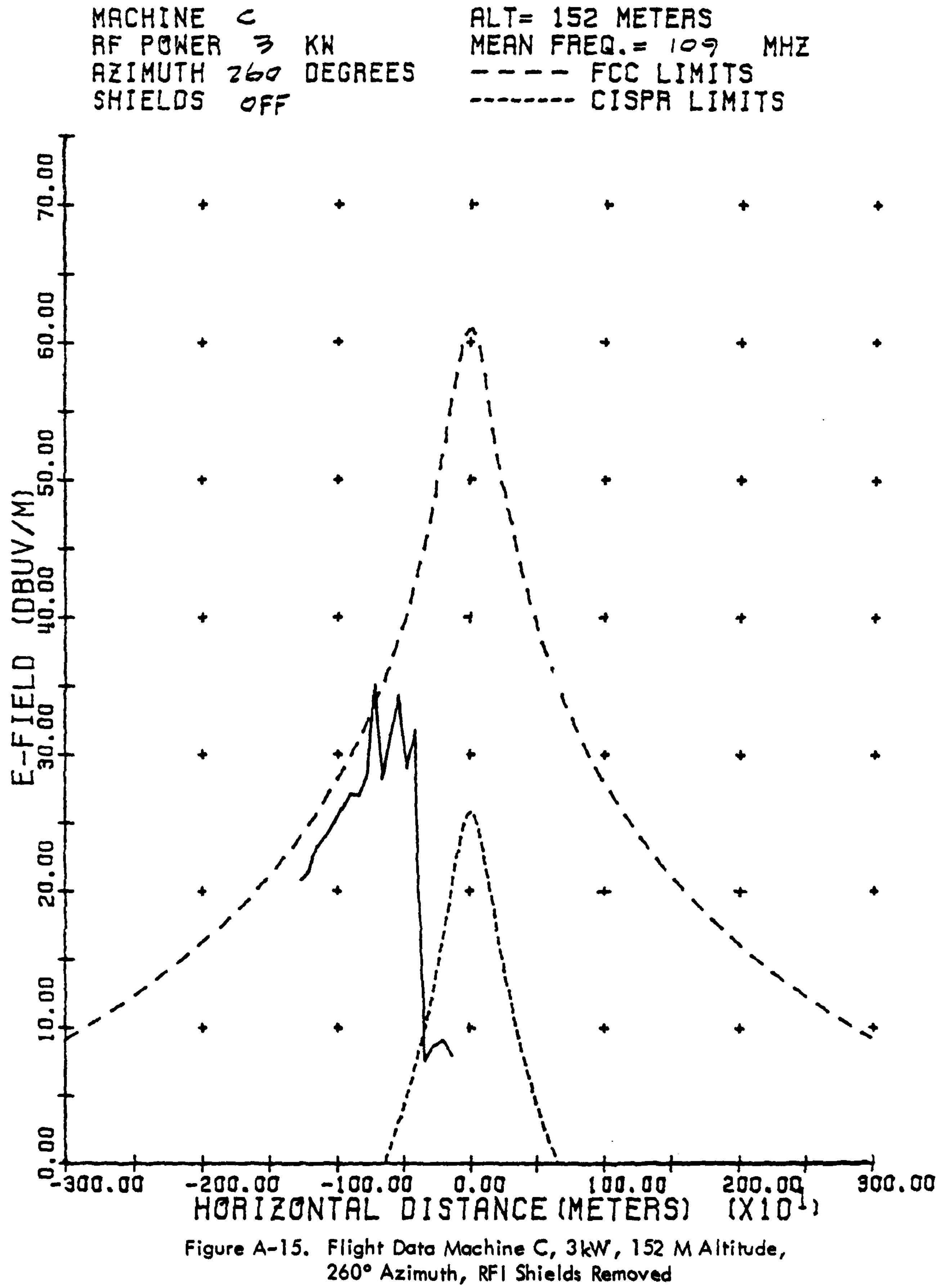


Figure A-15. Flight Data Machine C, 3kW, 152 M Altitude, 260° Azimuth, RFI Shields Removed

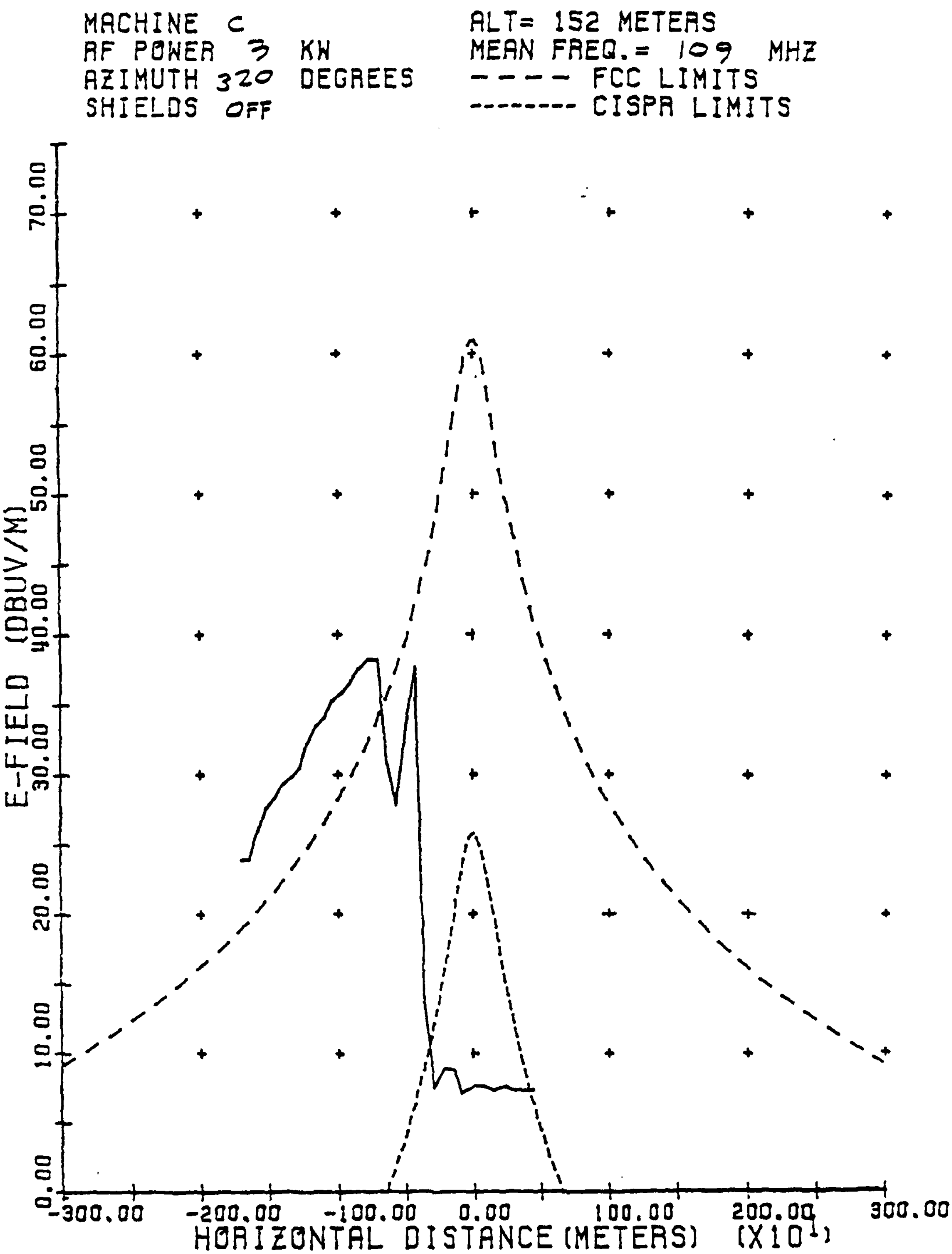


Figure A-16. Flight Data Machine C, 3 kW, 152 M Altitude, 320° Azimuth, RFI Shields Removed

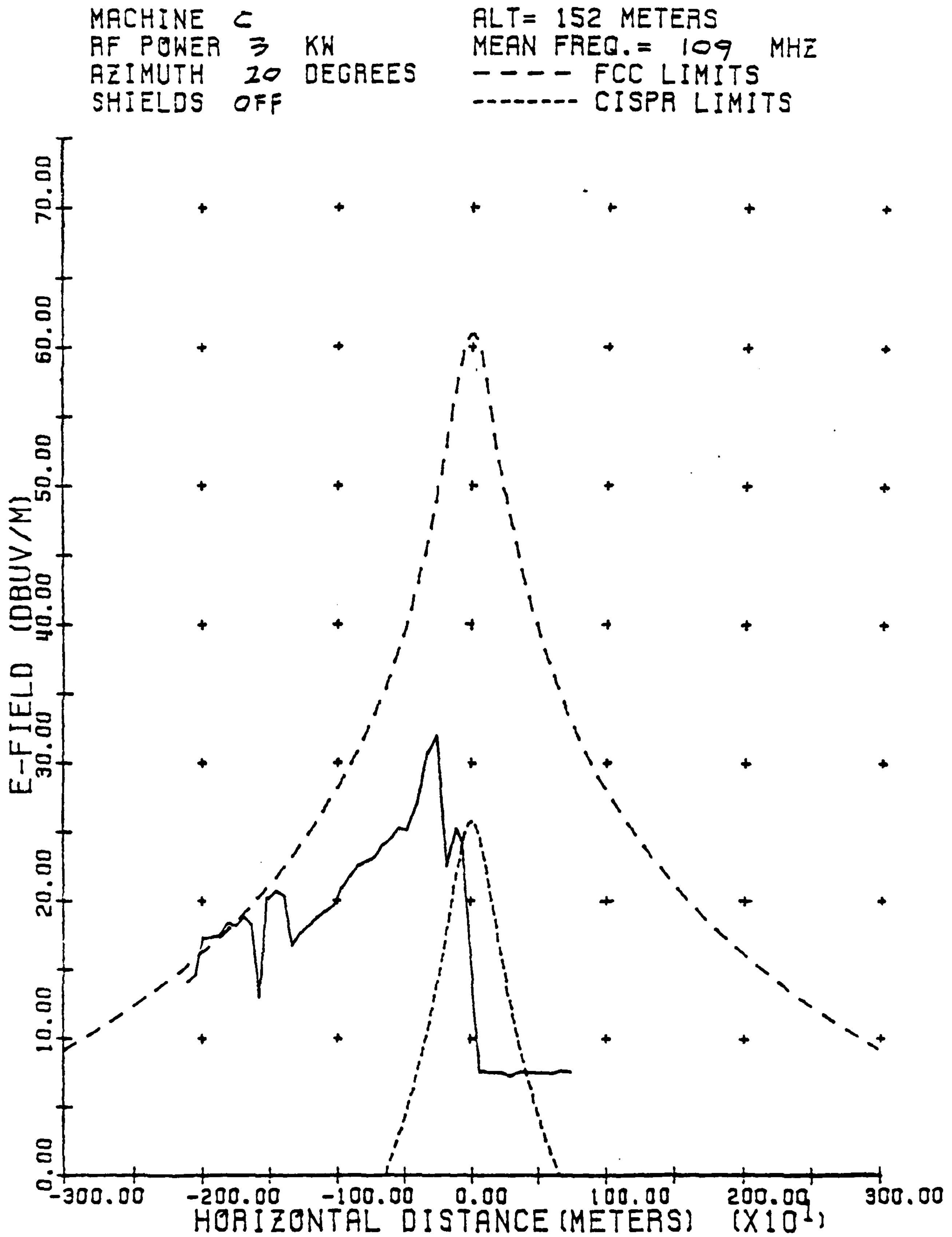


Figure A-17. Flight Data Machine C, 3 kW, 152 M Altitude, 20° Azimuth, RFI Shields Removed

AIRBORNE PLOTS - MACHINE D

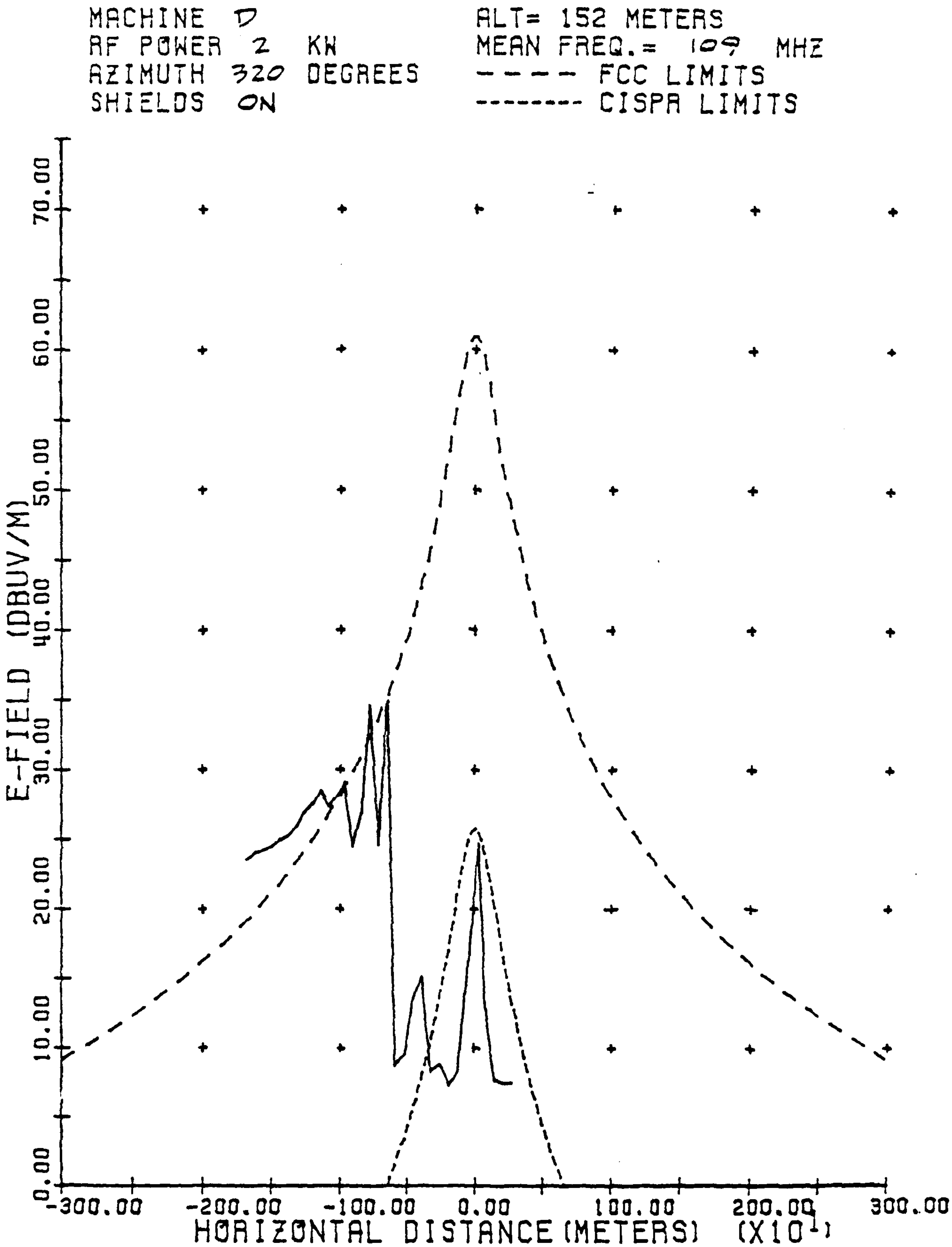


Figure A-18. Flight Data Machine D, 2 kW, 152 M Altitude, 320° Azimuth, RFI Shields In Place

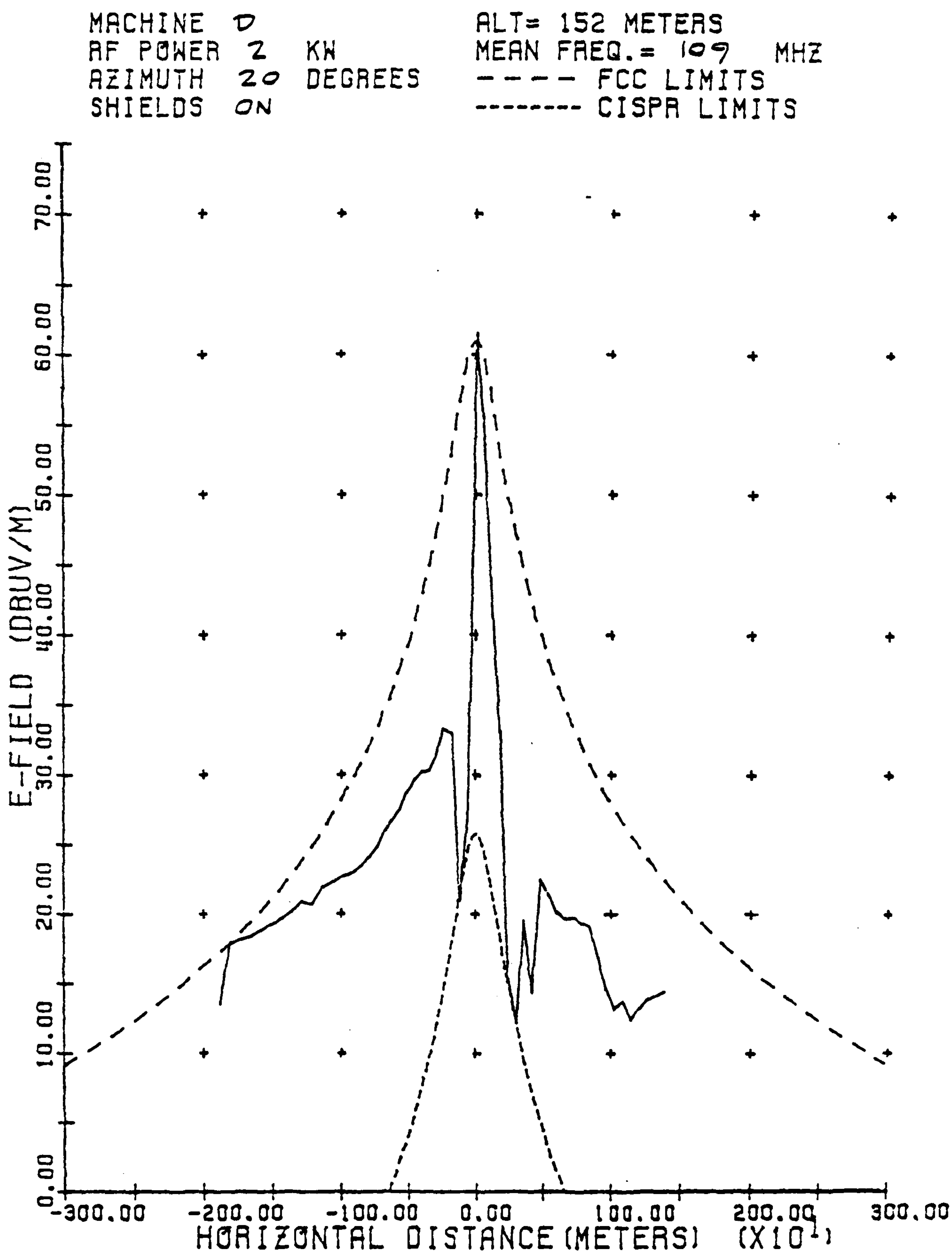


Figure A-19. Flight Data Machine D, 2 kW, 152 M Altitude, 20° Azimuth, RFI Shields In Place

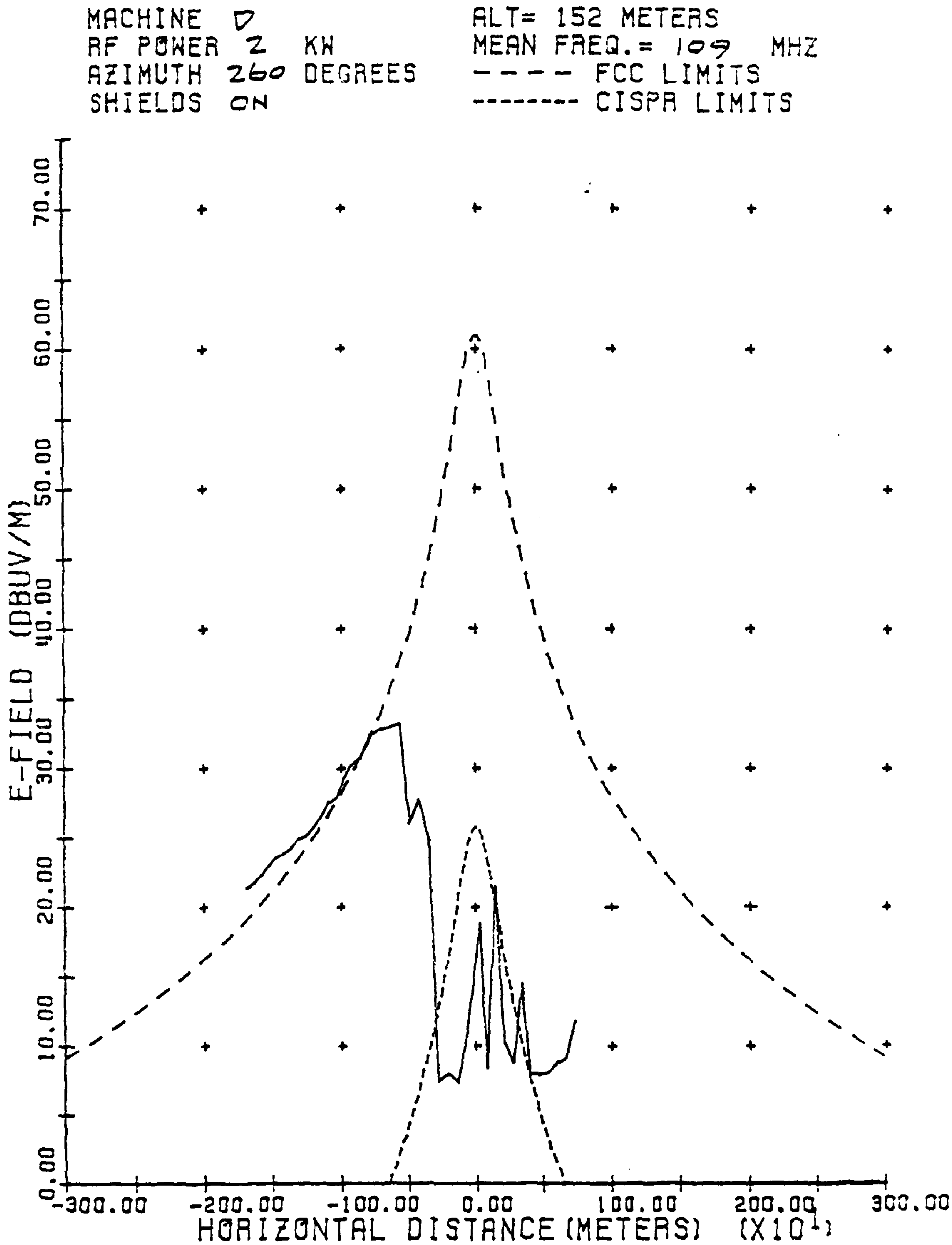


Figure A-20. Flight Data Machine D, 2 kW, 152 M Altitude, 260° Azimuth, RFI Shields In Place

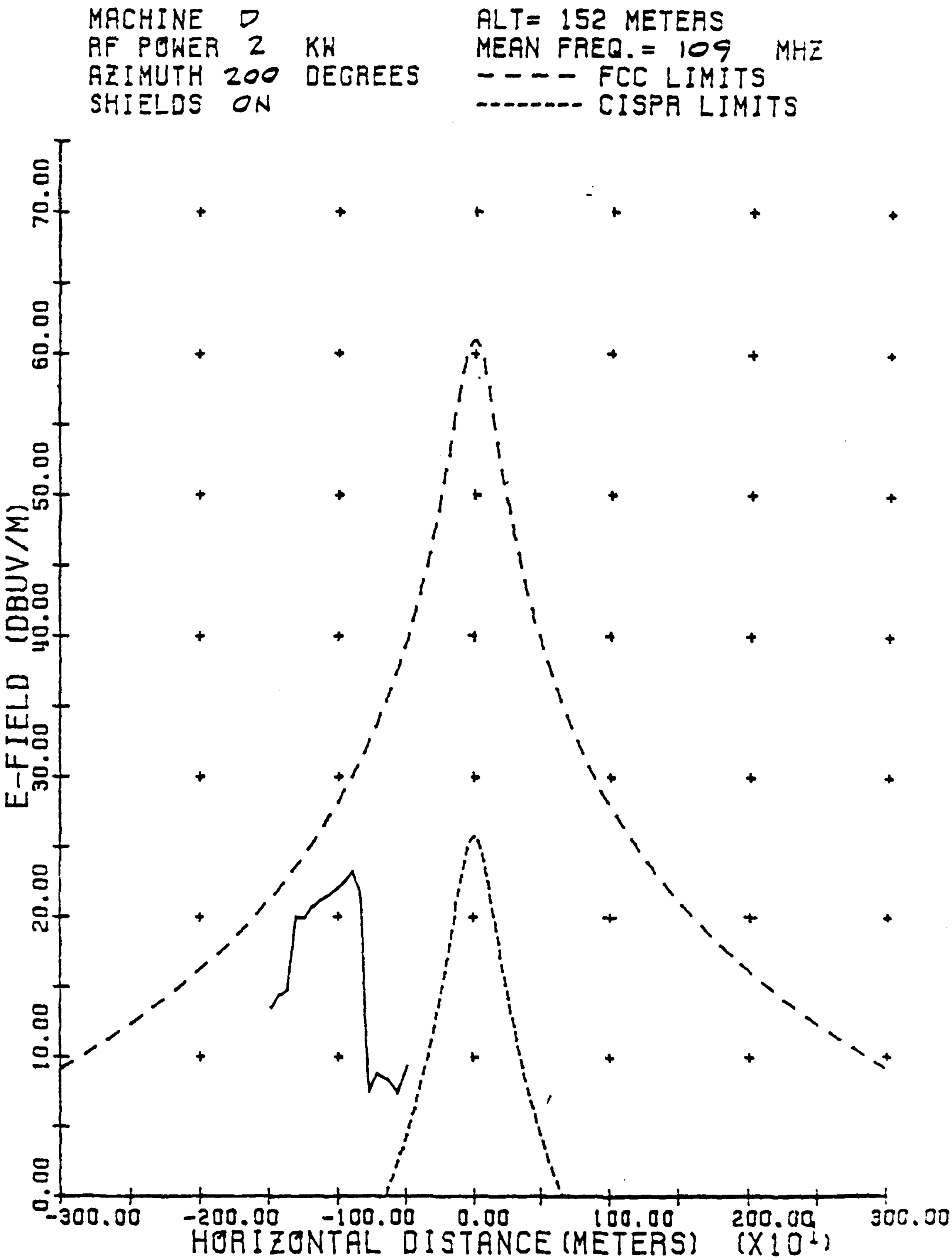


Figure A-21. Flight Data Machine D, 2 kW, 152 M Altitude, 200° Azimuth, RFI Shields In Place

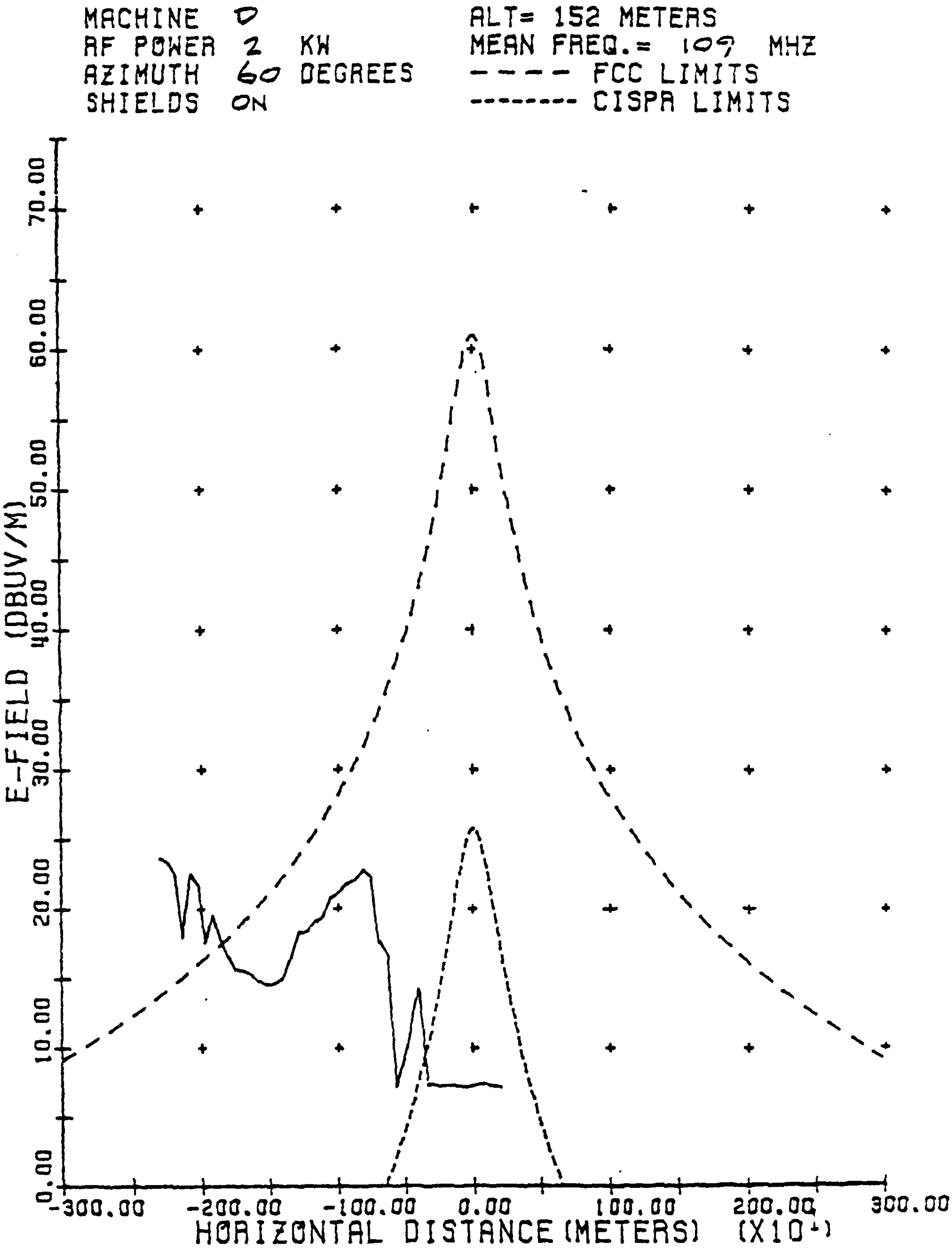


Figure A-22. Flight Data Machine D, 2 kW, 152 M Altitude, 60° Azimuth, RFI Shields In Place

Appendix B.

The material included here is taken from the reports furnished to Ohio University by the Elite Electronic Engineering Company. The test methods and results of the FCC, Part 18, tests conducted at their Waterman, Illinois, open field test site are described here. All of the measurement data for each of the ISM devices tested is included in this appendix except for the text describing the test procedure and equipment. This information is described in section IV of this report.

GROUND RF FIELD MEASUREMENTS - MACHINE A

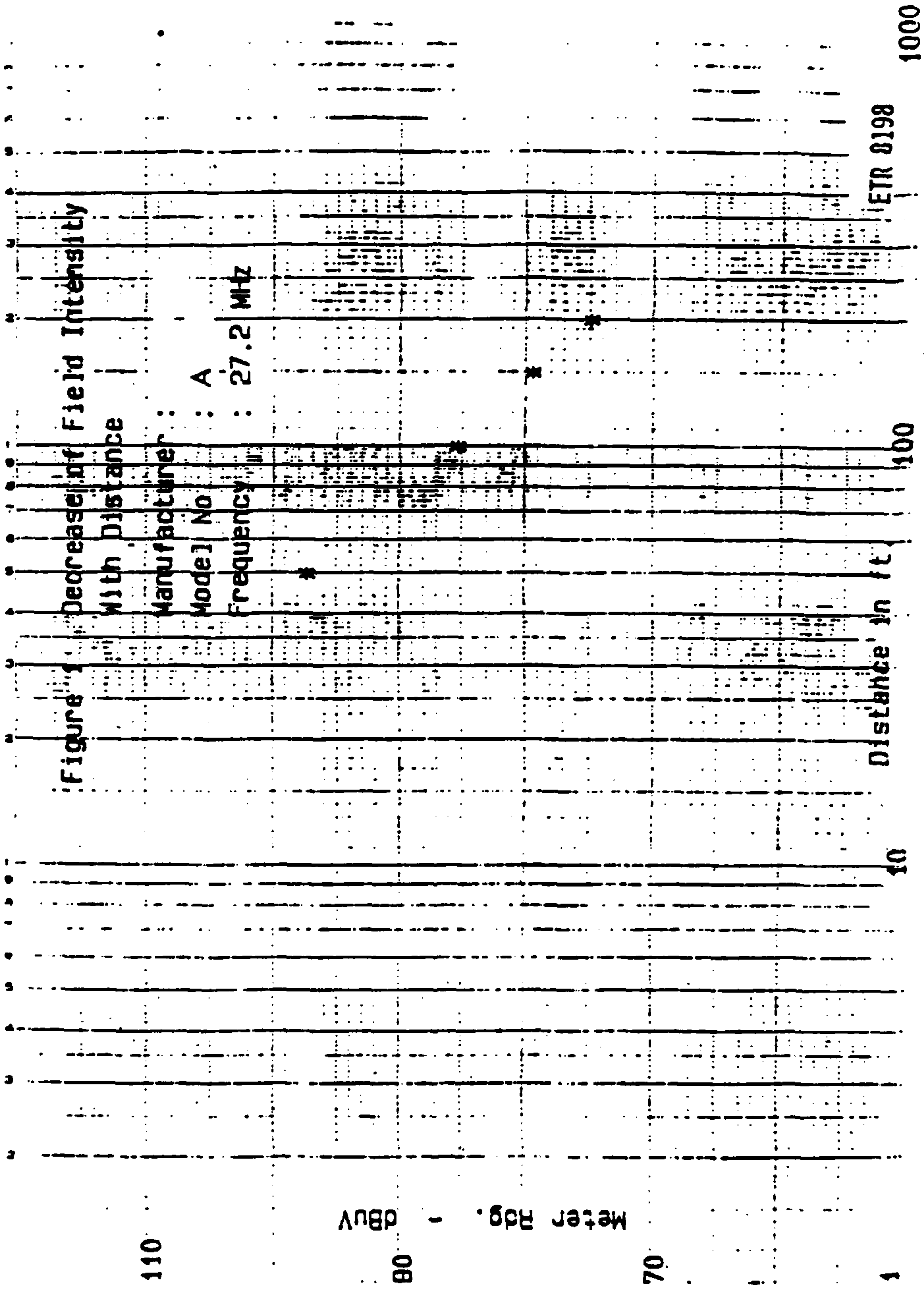


Figure B-1. Machine A Ground Determined Decay Exponent

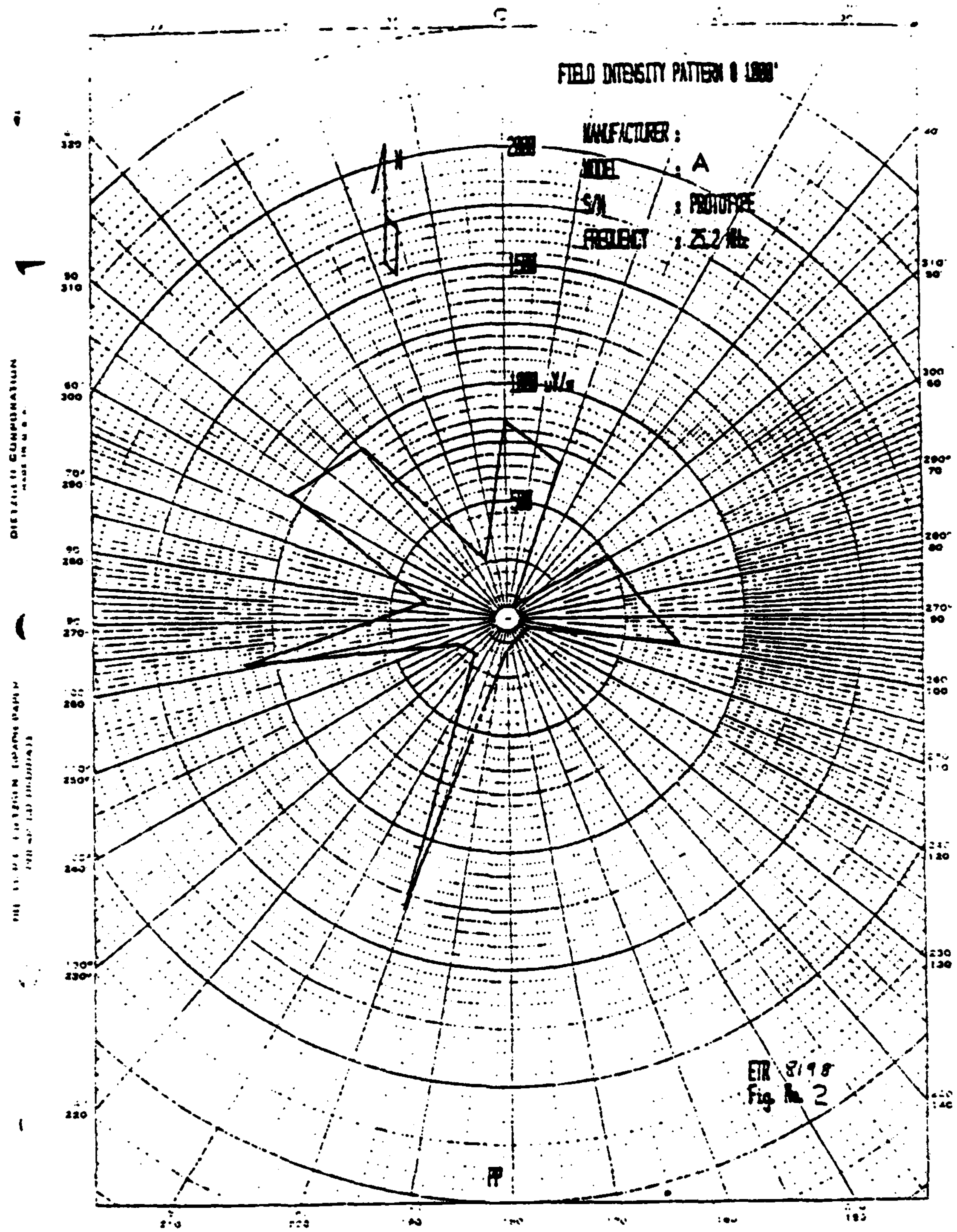


Figure B-2. Machine A Operating Frequency Field Intensity at 1000 feet

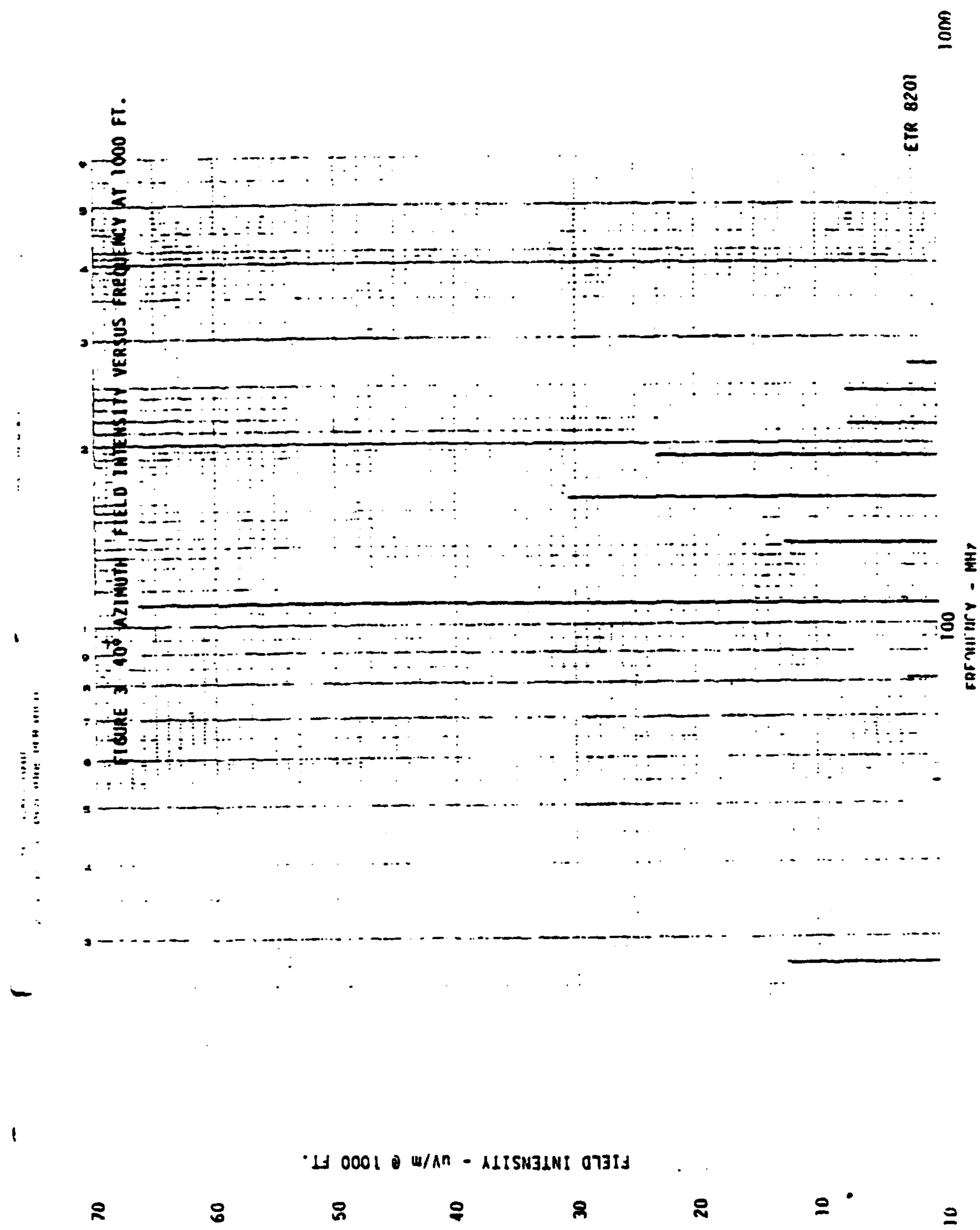


Figure B-3. Machine A Field Intensity vs. Frequency

ETR 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 0 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2262	74.6	11.0	-55.4	30.2	32.2	0.0
54.4523	40.0	13.0	-55.4	-2.5	0.8	10.0
81.6785	48.7	8.7	-55.4	2.0	1.3	10.0
108.9046	40.6	11.9	-55.4	-3.0	0.7	10.0
136.1308	53.1	12.3	-55.4	10.0	3.2	10.0
163.3569	51.4	19.5	-55.4	15.4	5.9	10.0
190.5831	32.7	18.3	-55.4	-4.5	0.6	10.0
217.8092	47.6	16.7	-55.4	8.9	2.8	10.0
245.0354	34.8	17.0	-55.4	-3.6	0.7	10.0
272.2615	40.2	17.3	-55.4	2.0	1.3	10.0

checked by: J. Stoffel

ETR 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 20 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2290	72.9	11.0	-55.4	28.5	26.5	0.0
54.4580	32.5	13.0	-55.4	-10.0	0.3	10.0
81.6870	36.1	8.7	-55.4	-10.6	0.3	10.0
108.9160	40.8	11.9	-55.4	-2.8	0.7	10.0
136.1450	53.6	12.3	-55.4	10.5	3.4	10.0
163.3739	54.0	19.5	-55.4	18.0	8.0	10.0
190.6029	39.1	18.3	-55.4	1.9	1.2	10.0
217.8319	39.1	16.7	-55.4	0.4	1.0	10.0
245.0607	33.7	17.0	-55.4	-4.7	0.6	10.0
272.2899	31.3	17.3	-55.4	-6.9	0.5	10.0

checked by: J Stoffel

ETK 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 Ft. Azimuth : 40 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2587	50.5	11.0	-55.4	6.1	2.0	0.0
54.5174	30.1	12.9	-55.4	-12.4	0.2	10.0
81.7761	27.2	8.7	-55.4	-19.5	0.1	10.0
109.0347	12.3	11.9	-55.4	-31.2	0.0	10.0
136.2934	36.6	12.4	-55.4	-6.5	0.5	10.0
163.5521	30.2	19.5	-55.4	-5.7	0.5	10.0
190.8108	25.9	18.2	-55.4	-11.3	0.3	10.0
218.0695	42.4	16.7	-55.4	3.7	1.5	10.0
245.3282	24.0	17.0	-55.4	-14.4	0.2	10.0
272.5869	20.5	17.3	-55.4	-17.7	0.1	10.0

checked by: J Stoffel

ETR 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 60 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2415	70.2	11.0	-55.4	25.8	19.4	0.0
54.4831	32.9	12.9	-55.4	-9.6	0.3	10.0
81.7246	45.4	8.7	-55.4	-1.3	0.9	10.0
108.9662	40.5	11.9	-55.4	-3.1	0.7	10.0
136.2077	42.0	12.4	-55.4	-1.1	0.9	10.0
163.4492	54.8	19.5	-55.4	18.8	8.8	10.0
190.6908	38.6	18.2	-55.4	1.4	1.2	10.0
217.9323	48.0	16.7	-55.4	9.3	2.9	10.0
245.1738	36.6	17.0	-55.4	-1.8	0.8	10.0
272.4154	39.9	17.3	-55.4	1.7	1.2	10.0

checked by: J S Toffel

ETK 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 80 degrees
Corrections based on a field decay exponent of 1.95

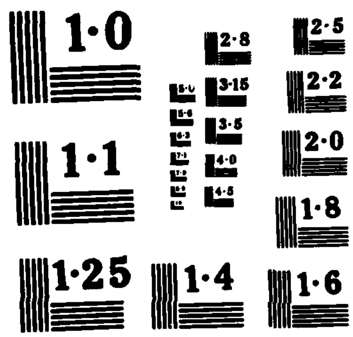
Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2377	71.1	11.0	-55.4	26.7	21.5	0.0
54.4753	19.7	12.9	-55.4	-22.8	0.1	10.0
81.7130	40.6	8.7	-55.4	-6.1	0.5	10.0
108.9506	36.9	11.9	-55.4	-6.7	0.5	10.0
136.1883	54.6	12.4	-55.4	11.5	3.8	10.0
163.4259	47.9	19.5	-55.4	11.9	4.0	10.0
190.6636	32.1	18.2	-55.4	-5.1	0.6	10.0
217.9013	39.2	16.7	-55.4	0.5	1.1	10.0
245.1389	22.8	17.0	-55.4	-15.6	0.2	10.0
272.3766	33.9	17.3	-55.4	-4.3	0.6	10.0

checked by: J Stoffel

AD-A157 724 MEASUREMENT OF RF (RADIO FREQUENCY) FIELDS ASSOCIATED WITH ISM (INDUSTRIA..(U) OHIO UNIV ATHENS AVIONICS ENGINEERING CENTER J D NICKUM ET AL. MAY 85 2/2

UNCLASSIFIED OU/AEC/EER-67-1 DOT/FAA/ES-84/2 F/G 20/14 NL

END



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

ETR 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 Ft. Azimuth : 100 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2449	73.6	11.0	-55.4	29.2	28.7	0.0
54.4898	27.0	12.9	-55.4	-15.5	0.2	10.0
81.7348	39.2	8.7	-55.4	-7.5	0.4	10.0
108.9797	16.1	11.9	-55.4	-27.5	0.0	10.0
136.2246	58.2	12.4	-55.4	15.1	5.7	10.0
163.4695	52.0	19.5	-55.4	16.0	6.3	10.0
190.7145	39.3	18.2	-55.4	2.1	1.3	10.0
217.9594	32.5	16.7	-55.4	-6.2	0.5	10.0
245.2043	30.4	17.0	-55.4	-8.0	0.4	10.0
272.4492	34.3	17.3	-55.4	-3.9	0.6	10.0

checked by: J Stoffel

ETR 8198
[illegible] ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 120 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1314	56.8	11.0	-55.4	12.4	4.1	0.0
54.2627	37.1	13.0	-55.4	-5.3	0.5	10.0
81.3941	32.9	8.7	-55.4	-13.9	0.2	10.0
108.5254	13.9	11.8	-55.4	-29.7	0.0	10.0
135.6568	33.7	12.2	-55.4	-9.5	0.3	10.0
162.7882	29.6	19.3	-55.4	-6.5	0.5	10.0
189.9195	29.2	18.4	-55.4	-7.9	0.4	10.0
217.0509	28.9	16.7	-55.4	-9.8	0.3	10.0
244.1823	19.3	17.0	-55.4	-19.1	0.1	10.0
271.3136	19.8	17.3	-55.4	-18.4	0.1	10.0

checked by: J Stoffel

ETR 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 140 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1398	56.4	11.0	-55.4	12.0	4.0	0.0
54.2795	40.8	13.0	-55.4	-1.6	0.8	10.0
81.4193	37.9	8.7	-55.4	-8.7	0.4	10.0
108.5590	20.1	11.8	-55.4	-23.5	0.1	10.0
135.6988	35.5	12.2	-55.4	-7.7	0.4	10.0
162.8385	27.7	19.3	-55.4	-8.4	0.4	10.0
189.9783	25.0	18.3	-55.4	-12.1	0.2	10.0
217.1180	25.5	16.7	-55.4	-13.2	0.2	10.0
244.2578	16.5	17.0	-55.4	-21.9	0.1	10.0
271.3975	20.4	17.3	-55.4	-17.8	0.1	10.0

checked by: J Stoffel

ETR 8198
ELLIOTT ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 160 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1197	57.2	11.0	-55.4	12.8	4.3	0.0
54.2394	43.1	13.0	-55.4	0.7	1.1	10.0
81.3590	40.3	8.7	-55.4	-6.0	0.5	10.0
108.4787	22.9	11.8	-55.4	-20.7	0.1	10.0
135.5984	28.2	12.2	-55.4	-14.4	0.2	10.0
162.7181	22.7	19.3	-55.4	-13.4	0.2	10.0
189.8377	26.0	18.4	-55.4	-11.1	0.3	10.0
216.9574	26.1	16.7	-55.4	-12.6	0.2	10.0
244.0771	17.9	17.0	-55.4	-20.5	0.1	10.0
271.1968	17.2	17.3	-55.4	-21.0	0.1	10.0

checked by: J Stoffel

ETS 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 180 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1481	60.0	11.0	-55.4	15.6	6.0	0.0
54.2962	42.1	13.0	-55.4	-0.3	1.0	10.0
81.4444	43.5	8.7	-55.4	-3.3	0.7	10.0
108.5925	27.2	11.9	-55.4	-16.4	0.2	10.0
135.7406	28.7	12.2	-55.4	-14.5	0.2	10.0
162.8887	32.5	19.3	-55.4	-3.6	0.7	10.0
190.0368	33.3	18.3	-55.4	-3.8	0.6	10.0
217.1849	26.2	16.7	-55.4	-12.5	0.2	10.0
244.3331	20.6	17.0	-55.4	-17.8	0.1	10.0
271.4812	20.3	17.3	-55.4	-17.9	0.1	10.0

checked by: J Stoffel

ETR 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 200 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2509	78.7	11.0	-55.4	34.3	51.6	0.0
54.5019	40.8	12.9	-55.4	-1.7	0.8	10.0
81.7528	48.1	8.7	-55.4	1.4	1.2	10.0
109.0038	40.1	11.9	-55.4	-3.4	0.7	10.0
136.2547	44.8	12.4	-55.4	1.7	1.2	10.0
163.5056	53.7	19.5	-55.4	17.8	7.7	10.0
190.7566	48.9	18.2	-55.4	11.7	3.8	10.0
218.0075	39.1	16.7	-55.4	0.4	1.0	10.0
245.2585	30.4	17.0	-55.4	-8.0	0.4	10.0
272.5094	37.1	17.3	-55.4	-1.1	0.9	10.0

checked by: J Stoffel

FTR 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 220 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1409	62.6	11.0	-55.4	18.2	8.1	0.0
54.2819	39.8	13.0	-55.4	-2.6	0.7	10.0
81.4228	51.5	8.7	-55.4	4.7	1.7	10.0
108.5637	26.6	11.8	-55.4	-17.0	0.1	10.0
135.7047	13.8	12.2	-55.4	-29.4	0.0	10.0
162.8456	31.6	19.3	-55.4	-4.5	0.6	10.0
189.9865	31.6	18.3	-55.4	-5.5	0.5	10.0
217.1275	33.7	16.7	-55.4	-5.0	0.6	10.0
244.2684	21.2	17.0	-55.4	-17.2	0.1	10.0
271.4094	17.0	17.3	-55.4	-21.2	0.1	10.0

checked by: J Stoffel

ETR 8198
ELLIOTT ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 240 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1401	63.9	11.0	-55.4	19.5	9.4	0.0
54.2801	39.2	13.0	-55.4	-3.2	0.7	10.0
81.4202	39.7	8.7	-55.4	-7.1	0.4	10.0
108.5603	20.3	11.8	-55.4	-23.3	0.1	10.0
135.7004	30.5	12.2	-55.4	-4.7	0.6	10.0
162.8404	29.9	19.3	-55.4	-6.2	0.5	10.0
189.9805	26.3	18.3	-55.4	-10.8	0.3	10.0
217.1206	31.6	16.7	-55.4	-7.1	0.4	10.0
244.2607	22.1	17.0	-55.4	-16.3	0.2	10.0
271.4007	17.7	17.3	-55.4	-20.5	0.1	10.0

checked by: J Stoffel

ETR 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 260 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2421	77.3	11.0	-55.4	32.9	43.9	0.0
54.4842	32.2	12.9	-55.4	-10.3	0.3	10.0
81.7262	36.9	8.7	-55.4	-9.8	0.3	10.0
108.9683	24.8	11.9	-55.4	-18.8	0.1	10.0
136.2104	47.0	12.4	-55.4	3.9	1.6	10.0
163.4525	50.8	19.5	-55.4	14.8	5.5	10.0
190.6946	25.1	18.2	-55.4	-12.1	0.2	10.0
217.9366	38.3	16.7	-55.4	-0.4	1.0	10.0
245.1787	33.7	17.0	-55.4	-4.7	0.6	10.0
272.4208	34.8	17.3	-55.4	-3.4	0.7	10.0

Checked by: J Stoffel

ETR 8198
ELLIOTT ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 280 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1523	67.2	11.0	-55.4	22.8	13.7	0.0
54.3046	31.9	13.0	-55.4	-10.5	0.3	10.0
81.4569	34.5	8.7	-55.4	-12.3	0.2	10.0
108.6092	19.0	11.9	-55.4	-24.6	0.1	10.0
135.7615	43.2	12.2	-55.4	-0.0	1.0	10.0
162.9138	24.3	19.4	-55.4	-11.8	0.3	10.0
190.0661	29.7	18.3	-55.4	-7.4	0.4	10.0
217.2184	27.0	16.7	-55.4	-11.7	0.3	10.0
244.3707	19.4	17.0	-55.4	-19.0	0.1	10.0
271.5230	19.8	17.3	-55.4	-18.4	0.1	10.0

checked by: J Stoffel

ETR 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 300 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2453	76.7	11.0	-55.4	32.3	41.0	0.0
54.4905	39.8	12.9	-55.4	-2.7	0.7	10.0
81.7358	43.7	8.7	-55.4	-3.0	0.7	10.0
108.9811	30.1	11.9	-55.4	-13.5	0.2	10.0
136.2263	53.0	12.4	-55.4	9.9	3.1	10.0
163.4716	55.3	19.5	-55.4	19.3	9.3	10.0
190.7169	34.2	18.2	-55.4	-3.0	0.7	10.0
217.9622	52.2	16.7	-55.4	13.5	4.7	10.0
245.2074	38.8	17.0	-55.4	0.4	1.0	10.0
272.4527	44.3	17.3	-55.4	6.1	2.0	10.0

checked by: J Stoffel

ETR 8198
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 320 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2502	75.7	11.0	-55.4	31.3	36.5	0.0
54.5004	38.8	12.9	-55.4	-3.7	0.7	10.0
81.7507	45.5	8.7	-55.4	-1.2	0.9	10.0
109.0009	34.0	11.9	-55.4	-9.5	0.3	10.0
136.2511	55.7	12.4	-55.4	12.6	4.3	10.0
163.5013	50.8	19.5	-55.4	14.9	5.5	10.0
190.7515	40.9	18.2	-55.4	3.7	1.5	10.0
218.0017	54.8	16.7	-55.4	16.1	6.4	10.0
245.2520	37.1	17.0	-55.4	-1.3	0.9	10.0
272.5022	40.0	17.3	-55.4	1.8	1.2	10.0

checked by: J Stoffel

ETR 8198

ELITE ELECTRONIC ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : A
S/N : PROTOTYPE
DATE TESTED : OCTOBER 11, 1983

Test Distance : 200 ft. Azimuth : 340 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1571	64.1	11.0	-55.4	19.7	9.6	0.0
54.3143	37.5	13.0	-55.4	-4.9	0.6	10.0
81.4714	44.7	8.7	-55.4	-2.1	0.8	10.0
108.6286	29.1	11.9	-55.4	-14.5	0.2	10.0
135.7857	37.6	12.2	-55.4	-5.6	0.5	10.0
162.9429	23.2	19.4	-55.4	-12.9	0.2	10.0
190.1000	24.6	18.3	-55.4	-12.5	0.2	10.0
217.2572	27.8	16.7	-55.4	-10.9	0.3	10.0
244.4143	20.8	17.0	-55.4	-17.6	0.1	10.0
271.5714	16.1	17.3	-55.4	-22.1	0.1	10.0

checked by: J Stoffel

GROUND RF FIELD MEASUREMENTS - MACHINE B

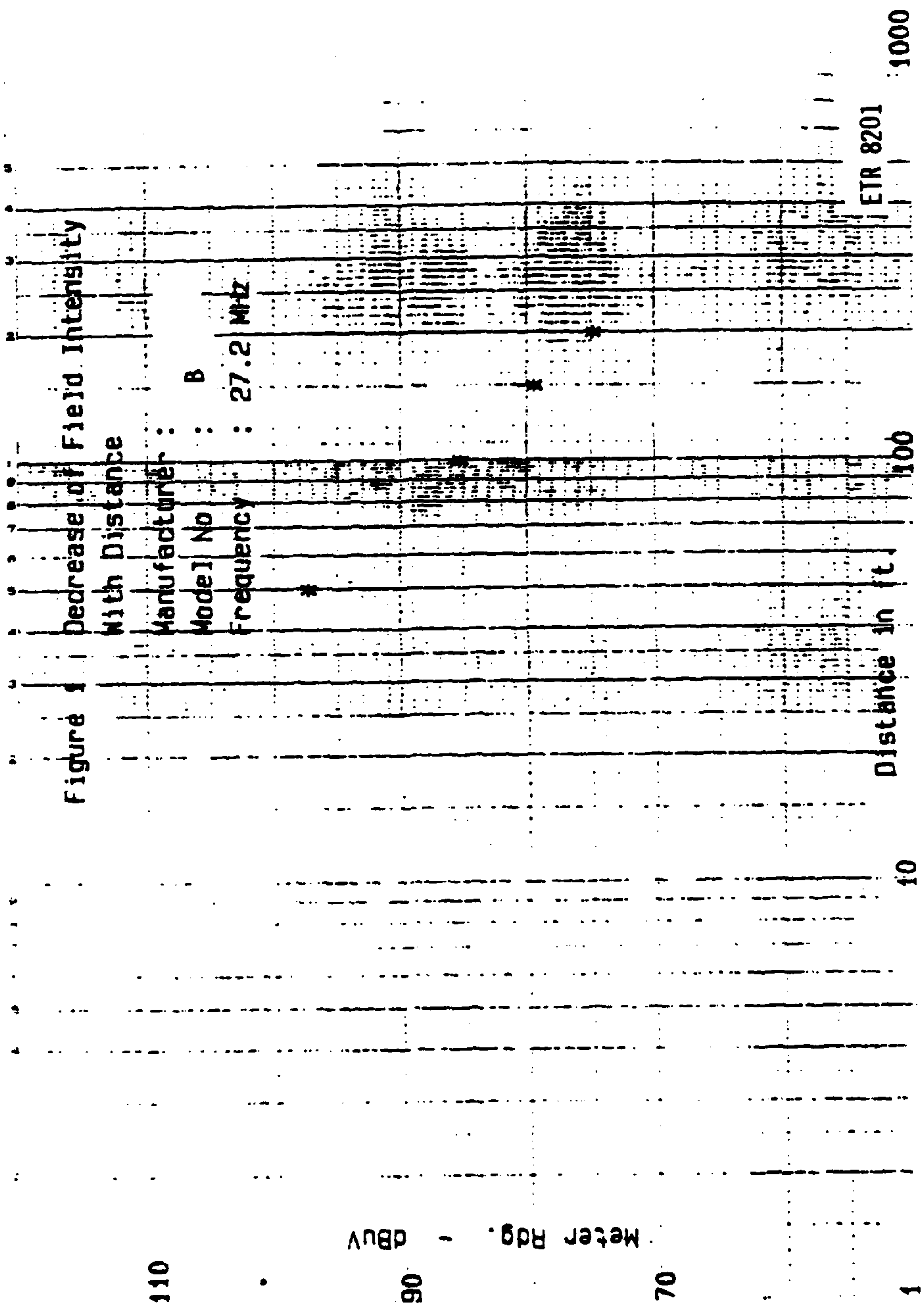


Figure B-4. Machine B Ground Determined Decay Exponent

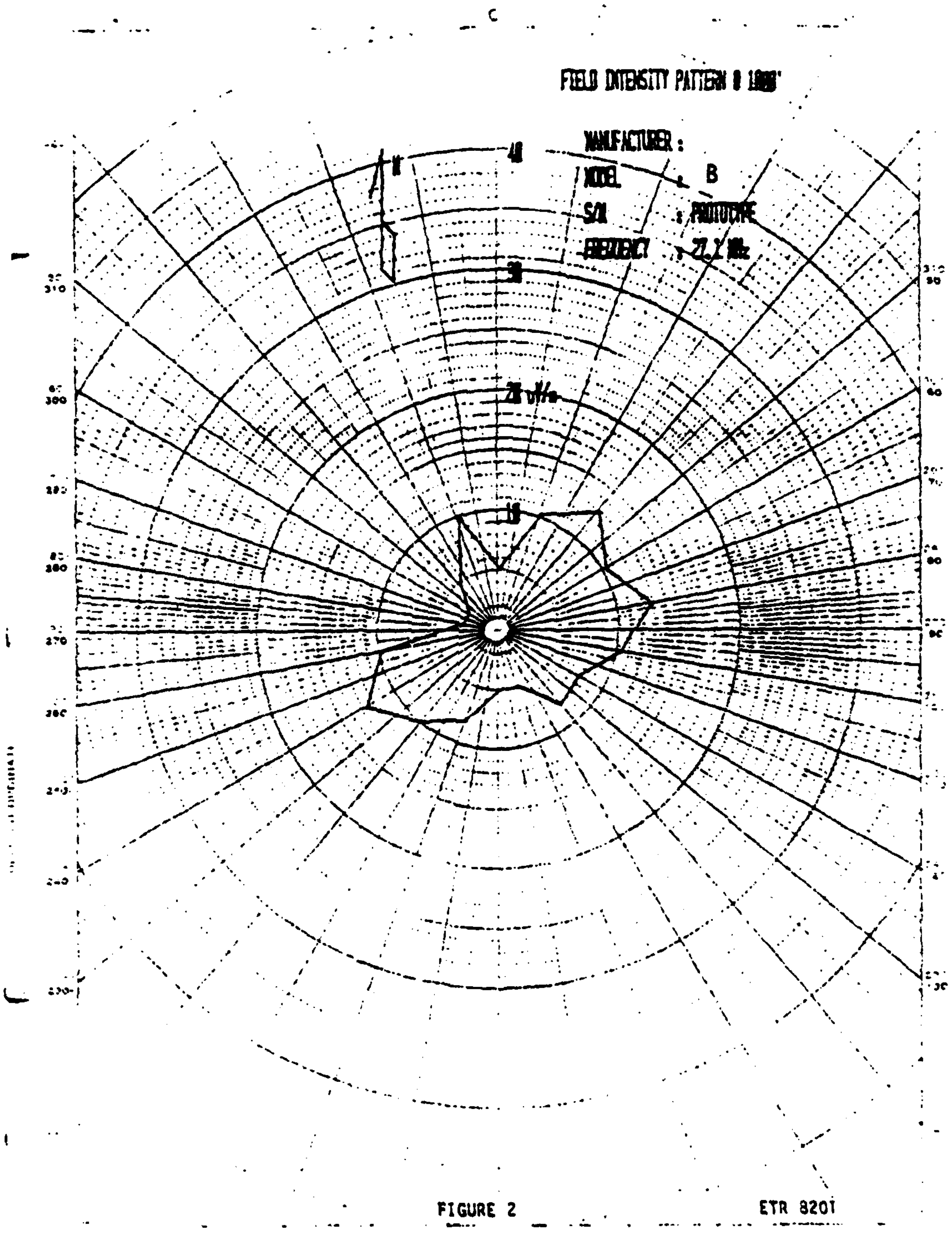


Figure B-5. Machine B Operating Frequency Field Intensity at 1000 feet

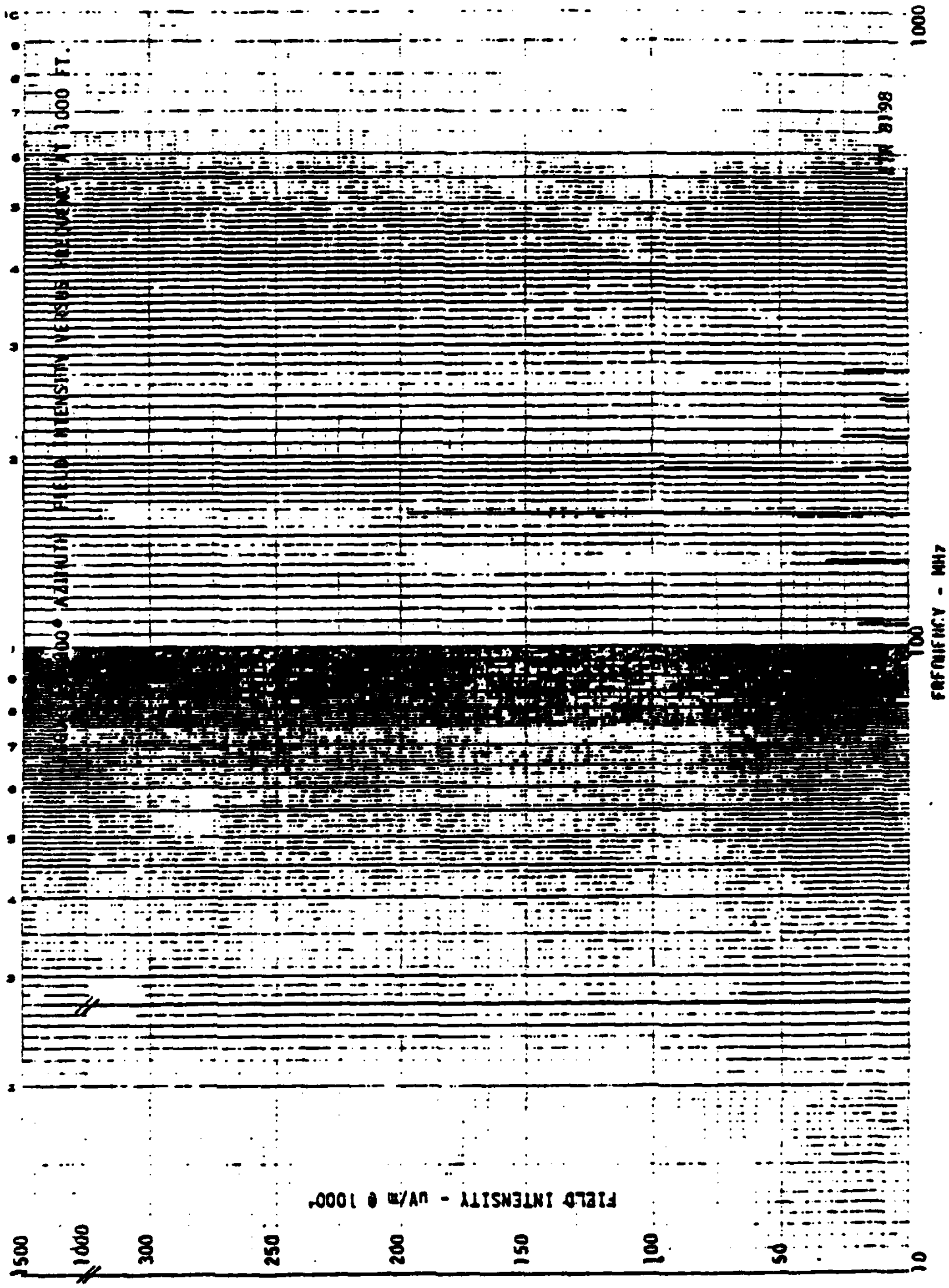


Figure B-6. Machine B Field Intensity vs. Frequency

ETP 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 0 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.0911	45.3	11.0	-72.1	-15.8	0.2	0.0
54.1821	31.3	13.1	-72.1	-27.7	0.0	10.0
81.2732	41.3	8.6	-72.1	-22.1	0.1	10.0
108.3642	71.3	11.8	-72.1	11.1	3.6	10.0
135.4553	54.8	12.1	-72.1	-5.1	0.6	10.0
162.5463	55.9	19.3	-72.1	3.1	1.4	10.0
189.6374	48.9	18.4	-72.1	-4.8	0.6	10.0
216.7284	42.7	16.7	-72.1	-12.6	0.2	10.0
243.8195	40.0	17.0	-72.1	-15.1	0.2	10.0
270.9105	39.0	17.3	-72.1	-15.8	0.2	10.0

Checked by: J. Stoffel

E1C 0201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 20 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1457	53.0	11.0	-72.1	-8.1	0.4	0.0
54.2915	23.9	13.0	-72.1	-35.1	0.0	10.0
81.4372	38.2	8.7	-72.1	-25.2	0.1	10.0
108.5829	70.6	11.9	-72.1	10.4	3.3	10.0
135.7287	53.6	12.2	-72.1	-6.2	0.5	10.0
162.8744	55.4	19.3	-72.1	2.7	1.4	10.0
190.0201	51.1	18.3	-72.1	-2.6	0.7	10.0
217.1659	42.7	16.7	-72.1	-12.6	0.2	10.0
244.3116	41.8	17.0	-72.1	-13.3	0.2	10.0
271.4573	37.5	17.3	-72.1	-17.3	0.1	10.0

checked by: J Stoffel

ETC 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 40 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1234	55.1	11.0	-72.1	-6.0	0.5	0.0
54.2468	26.3	13.0	-72.1	-32.7	0.0	10.0
81.3702	38.4	8.7	-72.1	-25.0	0.1	10.0
108.4936	68.6	11.8	-72.1	8.4	2.6	10.0
135.6170	53.0	12.2	-72.1	-6.9	0.5	10.0
162.7404	54.6	19.3	-72.1	1.9	1.2	10.0
189.8638	52.8	18.4	-72.1	-0.9	0.9	10.0
216.9871	44.4	16.7	-72.1	-10.9	0.3	10.0
244.1105	43.6	17.0	-72.1	-11.5	0.3	10.0
271.2339	34.0	17.3	-72.1	-20.8	0.1	10.0

checked by: J S Toffel

CTP 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 60 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1120	54.0	11.0	-72.1	-7.1	0.4	0.0
54.2240	29.8	13.1	-72.1	-29.2	0.0	10.0
81.3360	39.5	8.7	-72.1	-23.9	0.1	10.0
108.4480	69.6	11.8	-72.1	9.4	2.9	10.0
135.5599	50.2	12.2	-72.1	-9.7	0.3	10.0
162.6719	48.6	19.3	-72.1	-4.2	0.6	10.0
189.7839	40.0	18.4	-72.1	-13.7	0.2	10.0
216.8959	39.1	16.7	-72.1	-16.2	0.2	10.0
244.0079	46.2	17.0	-72.1	-8.9	0.4	10.0
271.1199	28.7	17.3	-72.1	-26.1	0.0	10.0

checked by: J. Stoffel

EIP 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMRER 11, 1983

Test Distance : 75 ft. Azimuth : 80 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1079	55.3	11.0	-72.1	-5.8	0.5	0.0
54.2158	31.2	13.1	-72.1	-27.8	0.0	10.0
81.3236	40.5	8.7	-72.1	-22.9	0.1	10.0
108.4315	67.7	11.8	-72.1	7.5	2.4	10.0
135.5394	50.4	12.2	-72.1	-9.5	0.3	10.0
162.6473	47.1	19.3	-72.1	-5.7	0.5	10.0
189.7552	44.2	18.4	-72.1	-9.5	0.3	10.0
216.8630	40.7	16.7	-72.1	-14.6	0.2	10.0
243.9709	44.0	17.0	-72.1	-11.1	0.3	10.0
271.0788	42.2	17.3	-72.1	-12.6	0.2	10.0

checked by: J S Toffel

ETR 3201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 100 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1114	53.1	11.0	-72.1	-8.0	0.4	0.0
54.2228	33.5	13.1	-72.1	-25.5	0.1	10.0
81.3343	38.2	8.7	-72.1	-25.2	0.1	10.0
108.4457	68.2	11.8	-72.1	8.0	2.5	10.0
135.5571	47.7	12.2	-72.1	-12.2	0.2	10.0
162.6685	48.4	19.3	-72.1	-4.4	0.6	10.0
189.7779	43.0	18.4	-72.1	-10.7	0.3	10.0
216.8914	50.5	16.7	-72.1	-4.8	0.6	10.0
244.0028	45.0	17.0	-72.1	-10.1	0.3	10.0
271.1142	43.7	17.3	-72.1	-11.1	0.3	10.0

checked by: J. Stoffel

ETR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : 8
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 120 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1120	51.4	11.0	-72.1	-9.7	0.3	0.0
54.2240	33.4	13.1	-72.1	-25.6	0.1	10.0
81.3360	30.3	8.7	-72.1	-33.1	0.0	10.0
108.4480	62.3	11.8	-72.1	2.1	1.3	10.0
135.5600	47.8	12.2	-72.1	-10.1	0.3	10.0
162.6721	51.1	19.3	-72.1	-1.7	0.8	10.0
187.7841	40.7	10.4	-72.1	-13.0	0.2	10.0
216.8961	46.6	16.7	-72.1	-8.7	0.4	10.0
244.0081	35.5	17.0	-72.1	-19.6	0.1	10.0
271.1201	43.8	17.3	-72.1	-11.0	0.3	10.0

checked by: J. Stoffel

FIR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 140 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1111	50.4	11.0	-72.1	-10.7	0.3	0.0
54.2223	33.7	13.1	-72.1	-25.3	0.1	10.0
81.3334	29.4	8.7	-72.1	-34.0	0.0	10.0
108.4445	65.0	11.8	-72.1	4.8	1.7	10.0
135.5556	49.1	12.2	-72.1	-10.8	0.3	10.0
162.6668	50.3	19.3	-72.1	-2.5	0.8	10.0
189.7779	40.2	18.4	-72.1	-13.5	0.2	10.0
216.8890	43.4	16.7	-72.1	-11.9	0.3	10.0
244.0002	34.1	17.0	-72.1	-21.0	0.1	10.0
271.1113	20.9	17.3	-72.1	-33.9	0.0	10.0

Checked by: J Stoffel

ETC 8203
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 160 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1074	47.5	11.0	-72.1	-13.6	0.2	0.0
54.2148	32.7	13.1	-72.1	-26.3	0.0	10.0
81.3222	29.9	8.7	-72.1	-33.5	0.0	10.0
108.4295	65.7	11.8	-72.1	5.5	1.9	10.0
135.5369	49.6	12.2	-72.1	-10.3	0.3	10.0
162.6443	48.4	19.3	-72.1	-4.4	0.6	10.0
189.7517	31.7	18.4	-72.1	-21.8	0.1	10.0
216.8591	42.9	16.7	-72.1	-12.4	0.2	10.0
243.9665	37.6	17.0	-72.1	-17.5	0.1	10.0
271.0739	39.6	17.3	-72.1	-15.2	0.2	10.0

checked by: J. Stoffel

ETR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 180 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1127	47.8	11.0	-72.1	-13.3	0.2	0.0
54.2254	28.6	13.1	-72.1	-30.4	0.0	10.0
81.3380	35.0	8.7	-72.1	-28.4	0.0	10.0
108.4507	65.8	11.8	-72.1	5.6	1.9	10.0
135.5634	48.6	12.2	-72.1	-11.3	0.3	10.0
162.6761	47.2	19.3	-72.1	-5.6	0.5	10.0
189.7888	34.4	18.4	-72.1	-19.3	0.1	10.0
216.9014	30.2	16.7	-72.1	-25.1	0.1	10.0
244.0141	42.6	17.0	-72.1	-12.5	0.2	10.0
271.1268	42.4	17.3	-72.1	-12.4	0.2	10.0

checked by: J Stoffel

FTR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 200 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1214	51.3	11.0	-72.1	-9.8	0.3	0.0
54.2427	21.0	13.0	-72.1	-38.0	0.0	10.0
81.3641	41.1	8.7	-72.1	-22.3	0.1	10.0
108.4854	67.1	11.8	-72.1	6.9	2.2	10.0
135.6068	50.4	12.2	-72.1	-9.5	0.3	10.0
162.7282	43.8	19.3	-72.1	-8.9	0.4	10.0
189.8495	51.2	18.4	-72.1	-2.5	0.8	10.0
216.9709	37.4	16.7	-72.1	-17.9	0.1	10.0
244.0922	46.7	17.0	-72.1	-8.4	0.4	10.0
271.2136	39.6	17.3	-72.1	-15.2	0.2	10.0

checked by: J. Stoffel

ETR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : 8
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 220 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1039	52.2	11.0	-72.1	-8.9	0.4	0.0
54.2077	21.2	13.1	-72.1	-37.8	0.0	10.0
81.3116	43.0	8.7	-72.1	-20.4	0.1	10.0
108.4154	66.0	11.8	-72.1	5.8	1.9	10.0
135.5193	45.9	12.2	-72.1	-14.0	0.2	10.0
162.6232	42.8	19.3	-72.1	-10.0	0.3	10.0
187.7270	44.3	18.4	-72.1	-9.4	0.3	10.0
216.8309	37.6	16.7	-72.1	-17.7	0.1	10.0
243.9347	43.1	17.0	-72.1	-12.0	0.3	10.0
271.0386	33.3	17.3	-72.1	-21.5	0.1	10.0

checked by: J Stoffel

ETR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 240 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1035	54.2	11.0	-72.1	-6.9	0.5	0.0
54.2069	25.3	13.1	-72.1	-33.7	0.0	10.0
81.3104	39.9	8.7	-72.1	-23.5	0.1	10.0
108.4138	66.1	11.8	-72.1	5.9	2.0	10.0
135.5173	47.2	12.2	-72.1	-12.7	0.2	10.0
162.6208	45.1	19.3	-72.1	-7.7	0.4	10.0
189.7242	43.3	18.4	-72.1	-10.4	0.3	10.0
216.8277	47.3	16.7	-72.1	-8.0	0.4	10.0
243.9311	46.6	17.0	-72.1	-8.5	0.4	10.0
271.0346	29.1	17.3	-72.1	-25.7	0.1	10.0

checked by: J Stoffel

ETR 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 260 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1078	52.9	11.0	-72.1	-8.2	0.4	0.0
54.2155	27.0	13.1	-72.1	-32.0	0.0	10.0
81.3233	36.6	8.7	-72.1	-26.8	0.0	10.0
108.4311	65.5	11.8	-72.1	5.3	1.8	10.0
135.5389	48.3	12.2	-72.1	-11.6	0.3	10.0
162.6466	47.6	19.3	-72.1	-5.2	0.6	10.0
189.7544	40.1	18.4	-72.1	-13.6	0.2	10.0
216.8622	40.1	16.7	-72.1	-15.2	0.2	10.0
243.9699	49.1	17.0	-72.1	-6.0	0.5	10.0
271.0777	34.8	17.3	-72.1	-20.0	0.1	10.0

checked by: J Stoffel

ETC 8?01
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 280 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1038	38.8	11.0	-72.1	-22.3	0.1	0.0
54.2076	25.0	13.1	-72.1	-34.0	0.0	10.0
81.3114	28.7	8.7	-72.1	-34.7	0.0	10.0
108.4152	65.6	11.8	-72.1	5.4	1.9	10.0
135.5190	48.8	12.2	-72.1	-11.1	0.3	10.0
162.6227	47.6	19.3	-72.1	-5.2	0.6	10.0
189.7265	45.3	18.4	-72.1	-8.4	0.4	10.0
216.8303	42.3	16.7	-72.1	-13.0	0.2	10.0
243.9341	48.9	17.0	-72.1	-6.2	0.5	10.0
271.0379	29.7	17.3	-72.1	-25.1	0.1	10.0

checked by: J Stoffel

ETR 0201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 300 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.0994	35.9	11.0	-72.1	-25.2	0.1	0.0
54.1989	26.7	13.1	-72.1	-32.3	0.0	10.0
81.2983	30.4	8.6	-72.1	-33.0	0.0	10.0
108.3978	65.5	11.8	-72.1	5.3	1.8	10.0
135.4972	45.2	12.2	-72.1	-14.7	0.2	10.0
162.5967	47.4	19.3	-72.1	-5.4	0.5	10.0
189.6961	42.1	18.4	-72.1	-11.6	0.3	10.0
216.7955	44.0	16.7	-72.1	-11.3	0.3	10.0
243.8950	49.0	17.0	-72.1	-6.1	0.5	10.0
270.9944	34.2	17.3	-72.1	-20.6	0.1	10.0

checked by: J. Stoffel

ETC 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 320 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1115	47.7	11.0	-72.1	-13.2	0.2	0.0
54.2231	29.2	13.1	-72.1	-29.8	0.0	10.0
81.3346	34.9	8.7	-72.1	-28.5	0.0	10.0
108.4462	67.1	11.8	-72.1	6.9	2.2	10.0
135.5577	45.2	12.2	-72.1	-14.7	0.2	10.0
162.6692	53.0	19.3	-72.1	0.2	1.0	10.0
189.7808	32.1	18.4	-72.1	-21.6	0.1	10.0
216.8923	40.7	16.7	-72.1	-14.6	0.2	10.0
244.0039	39.9	17.0	-72.1	-15.2	0.2	10.0
271.1154	42.8	17.3	-72.1	-12.0	0.3	10.0

checked by: J Stoffel

ETC 8201
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : B
S/N : PROTOTYPE
DATE TESTED : NOVEMBER 11, 1983

Test Distance : 75 ft. Azimuth : 340 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.0977	53.1	11.0	-72.1	-8.0	0.4	0.0
54.1995	30.3	13.1	-72.1	-28.7	0.0	10.0
81.2992	37.5	8.6	-72.1	-23.9	0.1	10.0
108.3990	69.6	11.8	-72.1	9.4	2.9	10.0
135.4987	52.7	12.2	-72.1	-7.2	0.4	10.0
162.5985	54.9	19.3	-72.1	2.1	1.3	10.0
189.6982	45.7	18.4	-72.1	-8.0	0.4	10.0
216.7979	40.4	16.7	-72.1	-14.9	0.2	10.0
243.8977	36.6	17.0	-72.1	-18.5	0.1	10.0
270.9974	41.1	17.3	-72.1	-13.7	0.2	10.0

checked by: J. Stoffel

GROUND RF FIELD MEASUREMENTS - MACHINE C

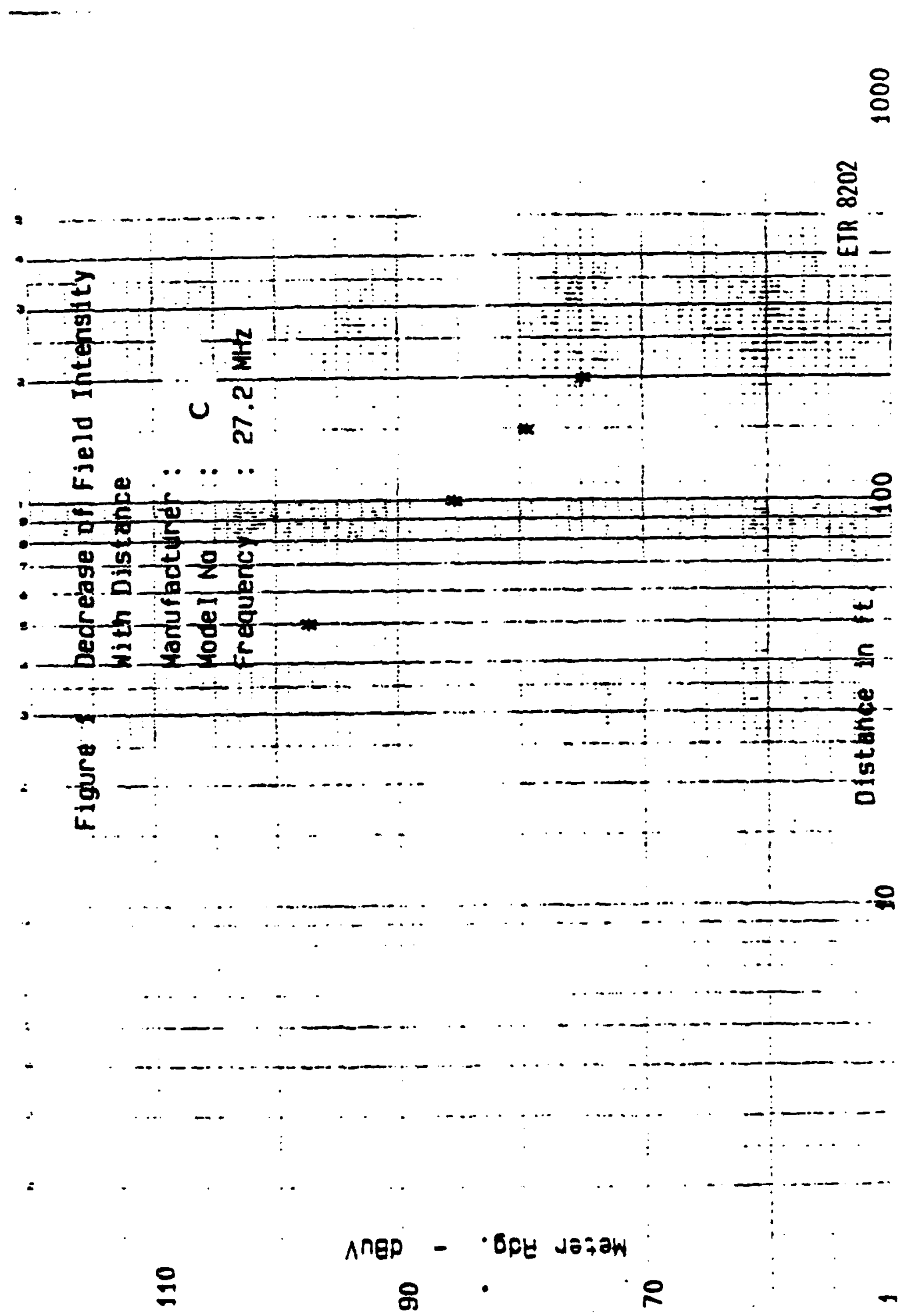


Figure B-7. Machine C Ground Determined Decay Exponent

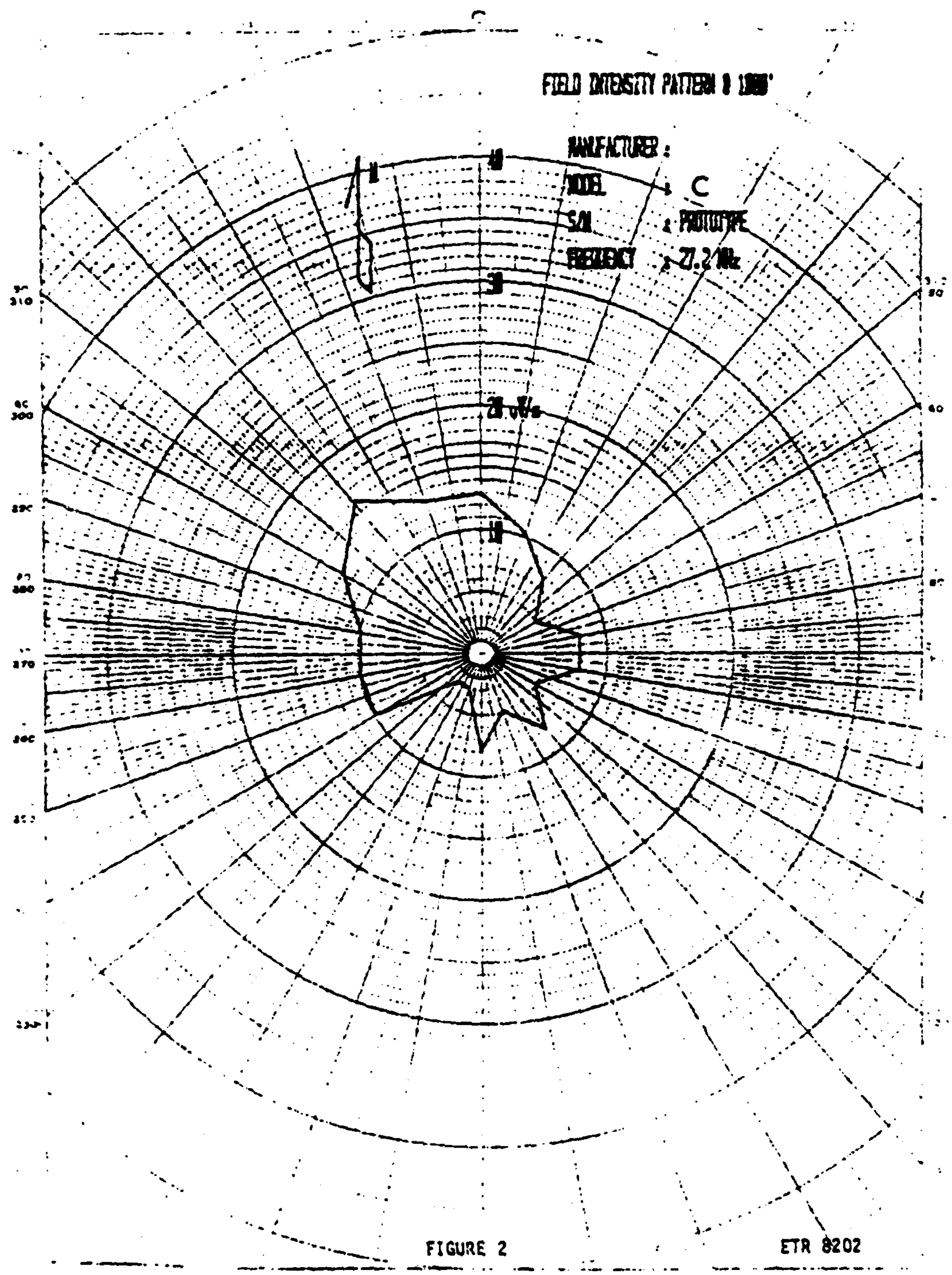


Figure B-8. Machine C Operating Frequency Field Intensity at 1000 feet

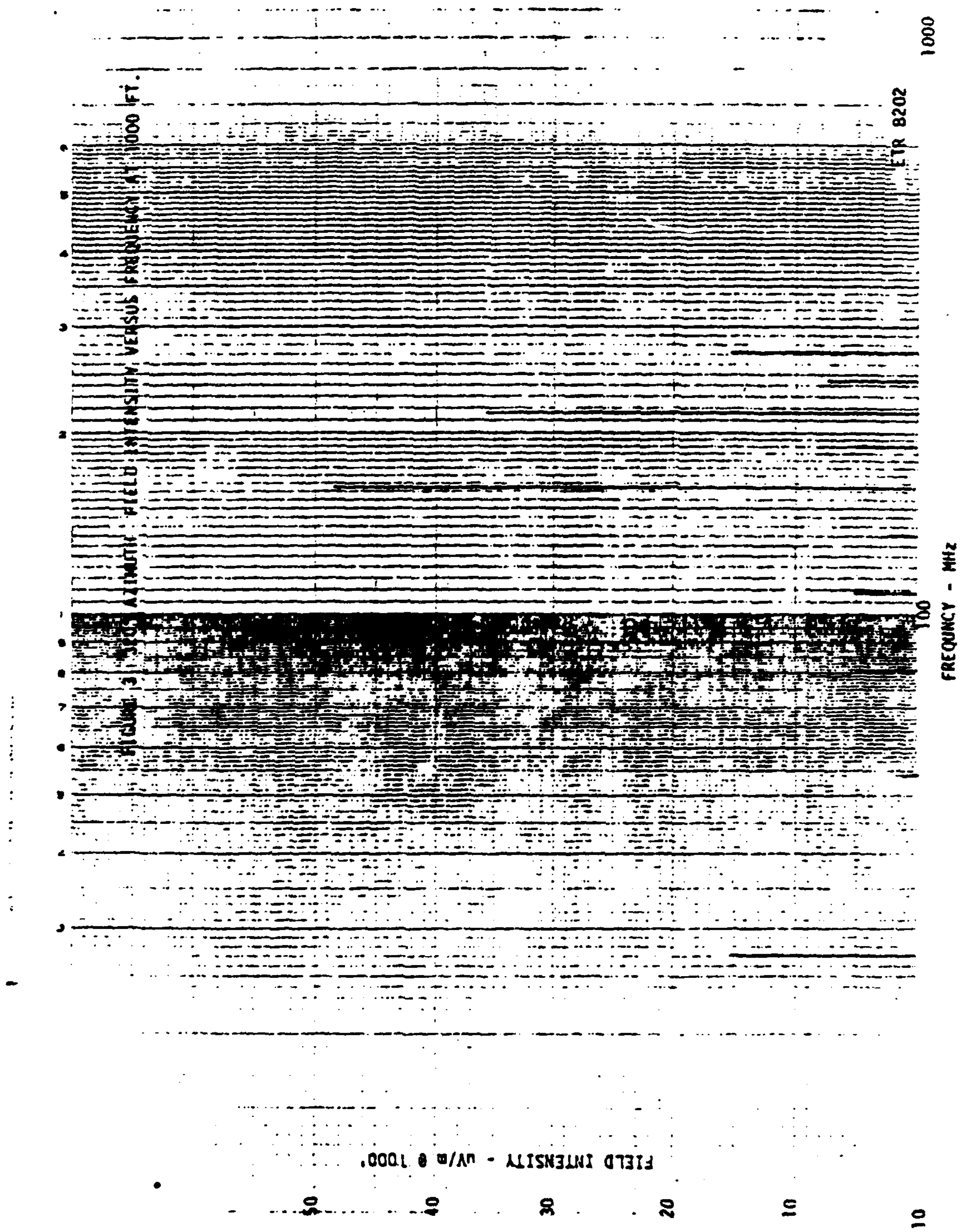


Figure B-9. Machine C Field Intensity vs. Frequency

[illegible]

[illegible]

MANUFACTURER : [illegible]
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 0 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1722	38.4	11.0	-55.4	-6.0	0.5	0.0
54.3445	13.4	13.0	-55.4	-29.0	0.0	10.0
81.5167	31.8	8.7	-55.4	-15.0	0.2	10.0
108.6890	28.2	11.9	-55.4	-15.4	0.2	10.0
135.8612	22.3	12.3	-55.4	-13.9	0.2	10.0
163.0334	43.2	19.4	-55.4	7.1	2.3	10.0
190.2057	22.7	18.3	-55.4	-9.4	0.3	10.0
217.3779	43.0	16.7	-55.4	4.3	1.6	10.0
244.5501	17.7	17.0	-55.4	-20.7	0.1	10.0
271.7224	34.1	17.3	-55.4	-4.1	0.6	10.0

checked by J. Stoffel

[illegible]

TITLE : [illegible]
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 20 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1734	36.8	11.0	-55.4	-7.6	0.4	0.0
54.3469	13.5	13.0	-55.4	-28.9	0.0	10.0
81.5203	30.5	8.7	-55.4	-16.3	0.2	10.0
108.6938	24.1	11.9	-55.4	-19.5	0.1	10.0
135.8672	27.2	12.3	-55.4	16.0	0.2	10.0
163.0407	45.4	19.4	-55.4	9.3	2.9	10.0
190.2141	26.4	18.3	-55.4	-10.7	0.3	10.0
217.3876	41.5	16.7	-55.4	2.8	1.4	10.0
244.5610	22.7	17.0	-55.4	-15.7	0.2	10.0
271.7345	29.3	17.3	-55.4	-8.9	0.4	10.0

checked by: J. Stoffel

[illegible]

[illegible]

[illegible]

[illegible] FCC PART 15G [illegible]

MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 40 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1763	34.5	11.0	-55.4	-9.9	0.3	0.0
54.3526	13.2	13.0	-55.4	-29.2	0.0	10.0
81.5289	28.1	8.7	-55.4	-18.7	0.1	10.0
108.7051	17.9	11.9	-55.4	-25.7	0.1	10.0
135.8814	23.1	12.3	-55.4	-20.1	0.1	10.0
163.0577	45.0	19.4	-55.4	8.9	2.8	10.0
190.2340	22.2	18.3	-55.4	-14.9	0.2	10.0
217.4103	42.0	16.7	-55.4	3.3	1.5	10.0
244.5866	24.9	17.0	-55.4	-13.5	0.2	10.0
271.7629	20.6	17.3	-55.4	-17.6	0.1	10.0

Checked by: J. Stoffel

[illegible]
[illegible]
[illegible]

[illegible] : [illegible]
[illegible] :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 60 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1731	32.1	11.0	-55.4	-12.3	0.2	0.0
54.3462	15.8	13.0	-55.4	-26.6	0.0	10.0
81.5193	26.5	8.7	-55.4	-20.3	0.1	10.0
108.6924	23.3	11.9	-55.4	-20.3	0.1	10.0
135.8655	22.7	12.3	-55.4	-20.5	0.1	10.0
163.0386	35.7	19.4	-55.4	-0.4	1.0	10.0
190.2117	28.4	18.3	-55.4	-16.7	0.1	10.0
217.3848	40.5	16.7	-55.4	1.8	1.2	10.0
244.5579	17.3	17.0	-55.4	-21.1	0.1	10.0
271.7310	27.6	17.3	-55.4	-10.6	0.3	10.0

checked by J. Stoffel

[illegible]
[illegible] ENGINEERING CO.
[illegible]

[illegible] : [illegible]
MANUFACTURER : [illegible]
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 80 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1783	32.6	11.0	-55.4	-11.8	0.3	0.0
54.3565	14.9	13.0	-55.4	-27.5	0.0	10.0
81.5348	24.6	8.7	-55.4	-22.2	0.1	10.0
108.7130	24.6	11.9	-55.4	-19.0	0.1	10.0
135.8913	27.1	12.3	-55.4	-16.1	0.2	10.0
163.0695	20.3	19.4	-55.4	-15.8	0.2	10.0
190.2478	19.9	18.3	-55.4	-17.2	0.1	10.0
217.4260	42.4	16.7	-55.4	3.7	1.5	10.0
244.6043	25.6	17.0	-55.4	-12.8	0.2	10.0
271.7826	30.8	17.3	-55.4	-7.4	0.4	10.0

checked by: J. Stoffel

[illegible]

DATA [illegible]

TEST : FCC PART 18D INDUSTRIAL [illegible]
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 100 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1818	34.1	11.0	-55.4	-10.3	0.3	0.0
54.3637	13.7	13.0	-55.4	-28.8	0.0	10.0
81.5455	27.7	8.7	-55.4	-19.1	0.1	10.0
108.7273	28.6	11.9	-55.4	-15.0	0.2	10.0
135.7092	27.7	12.3	-55.4	-15.5	0.2	10.0
163.0910	40.6	19.4	-55.4	4.6	1.7	10.0
190.2728	28.4	18.3	-55.4	-8.7	0.4	10.0
217.4547	32.9	16.7	-55.4	-5.8	0.5	10.0
244.6365	28.9	17.0	-55.4	-9.5	0.3	10.0
271.8183	38.0	17.3	-55.4	-0.2	1.0	10.0

checked by: J. Stoffel

ET[illegible]

[illegible] ELECTRONIC ENGINEERING [illegible]

[illegible]

[illegible] : [illegible] ART FOR INDUSTRIAL [illegible] EQUIPMENT
[illegible] :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 120 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1823	32.4	11.0	-55.4	-12.0	0.2	0.0
54.3647	13.5	13.0	-55.4	-29.0	0.0	10.0
81.5470	31.0	8.7	-55.4	-15.8	0.2	10.0
108.7293	28.6	11.9	-55.4	-15.0	0.2	10.0
135.9116	26.7	12.3	-55.4	-16.5	0.2	10.0
163.0940	46.7	19.4	-55.4	10.7	3.4	10.0
190.2763	34.7	18.3	-55.4	-2.4	0.8	10.0
217.4586	43.0	16.7	-55.4	4.3	1.6	10.0
244.6410	22.9	17.0	-55.4	-15.5	0.2	10.0
271.8233	37.6	17.3	-55.4	-0.6	0.9	10.0

Checked by: J Stoffel

[illegible]
[illegible] ELECTRONIC ENGINEERING CO
DATA PAGE

TEST : [illegible] PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 140 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1861	32.5	11.0	-55.4	-11.9	0.3	0.0
54.3722	13.5	13.0	-55.4	-29.0	0.0	10.0
81.5582	31.5	8.7	-55.4	-15.3	0.2	10.0
108.7443	29.2	11.9	-55.4	-14.4	0.2	10.0
135.9304	31.8	12.3	-55.4	-11.4	0.3	10.0
163.1165	46.1	19.4	-55.4	10.1	3.2	10.0
190.3025	33.7	18.3	-55.4	-3.4	0.7	10.0
217.4886	41.5	16.7	-55.4	2.8	1.4	10.0
244.6747	28.4	17.0	-55.4	-10.0	0.3	10.0
271.8608	37.0	17.3	-55.4	-1.2	0.9	10.0

checked by: J. Stobbe

[illegible]
[illegible]
[illegible]

[illegible] FCC PART [illegible] [illegible] EQUIPMENT
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 160 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1926	31.7	11.0	-55.4	-12.7	0.2	0.0
54.3851	14.5	13.0	-55.4	-28.0	0.0	10.0
81.5777	30.4	8.7	-55.4	-16.4	0.2	10.0
108.7702	27.4	11.9	-55.4	-16.2	0.2	10.0
135.9628	32.6	12.3	-55.4	-10.5	0.3	10.0
163.1553	46.5	19.4	-55.4	10.5	3.3	10.0
190.3479	29.9	18.3	-55.4	7.3	0.4	10.0
217.5404	43.5	16.7	-55.4	4.8	1.7	10.0
244.7330	31.7	17.0	-55.4	-6.7	0.5	10.0
271.9255	32.8	17.3	-55.4	-5.4	0.5	10.0

Checked by: J. Stobbe

[illegible]
[illegible] ELECTRONIC ENGINEERING [illegible]
DATA [illegible]

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 180 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1942	32.5	11.0	-55.4	-11.9	0.3	0.0
54.3884	14.4	13.0	-55.4	-28.1	0.0	10.0
81.5826	30.1	8.7	-55.4	-16.7	0.1	10.0
108.7768	27.2	11.9	-55.4	-16.4	0.2	10.0
135.9710	30.7	12.3	-55.4	-12.4	0.2	10.0
163.1652	48.2	19.4	-55.4	12.2	4.1	10.0
190.3594	25.3	18.3	-55.4	-11.7	0.3	10.0
217.5536	45.3	16.7	-55.4	6.6	2.1	10.0
244.7477	31.6	17.0	-55.4	-6.8	0.5	10.0
271.9421	29.9	17.3	-55.4	-8.3	0.4	10.0

Checked by: J. Stobbe

[illegible]

[illegible]

[illegible]

TEST : [illegible] PART 18 [illegible] HEATING [illegible]
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 200 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1888	26.8	11.0	-55.4	-17.6	0.1	0.0
54.3776	14.1	13.0	-55.4	-28.4	0.0	10.0
81.5664	29.6	8.7	-55.4	-17.2	0.1	10.0
108.7552	26.3	11.9	-55.4	-17.3	0.1	10.0
135.9440	30.4	12.3	-55.4	-12.8	0.2	10.0
163.1328	42.4	19.4	-55.4	6.4	2.1	10.0
170.3216	28.7	18.3	-55.4	8.4	0.4	10.0
217.5104	41.2	16.7	-55.4	2.5	1.3	10.0
244.6992	29.7	17.0	-55.4	-8.7	0.4	10.0
271.8880	36.4	17.3	-55.4	-1.8	0.8	10.0

checked by: J. Stoffel

[illegible]

[illegible]

[illegible]

[illegible]

MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 220 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1926	27.4	11.0	-55.4	-17.0	0.1	0.0
54.3853	14.1	13.0	-55.4	-28.4	0.0	10.0
81.5779	30.3	8.7	-55.4	-16.5	0.2	10.0
108.7705	26.1	11.9	-55.4	-17.5	0.1	10.0
135.9632	32.1	12.3	-55.4	-11.0	0.3	10.0
163.1558	41.9	19.4	-55.4	5.9	2.0	10.0
190.3485	27.6	18.3	-55.4	-7.6	0.4	10.0
217.5411	35.4	16.7	-55.4	-3.3	0.7	10.0
244.7337	27.1	17.0	-55.4	-11.3	0.3	10.0
271.9264	32.0	17.3	-55.4	-6.2	0.5	10.0

checked by: J. Stoffel

[illegible]

[illegible] :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 240 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.2012	36.7	11.0	-55.4	-7.7	0.4	0.0
54.4024	12.6	13.0	-55.4	-29.9	0.0	10.0
81.6036	29.9	8.7	-55.4	-16.9	0.1	10.0
108.8048	28.0	11.9	-55.4	-15.6	0.2	10.0
136.0060	31.5	12.3	-55.4	-11.6	0.3	10.0
163.2072	43.7	19.4	-55.4	7.7	2.4	10.0
170.4084	26.2	18.3	-55.4	-11.0	0.3	10.0
217.6096	44.8	16.7	-55.4	6.1	2.0	10.0
244.8108	24.3	17.0	-55.4	-14.1	0.2	10.0
272.0120	32.1	17.3	-55.4	-6.1	0.5	10.0

checked by: J. Stoffel

[illegible]
[illegible]
[illegible]

UNIT : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 260 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1734	37.5	11.0	-55.4	-6.9	0.4	0.0
54.3467	12.0	13.0	-55.4	-30.4	0.0	10.0
81.5201	29.1	8.7	-55.4	-17.7	0.1	10.0
108.6935	27.7	11.9	-55.4	-15.9	0.2	10.0
135.8668	30.0	12.3	-55.4	-13.2	0.2	10.0
163.0402	38.9	19.4	-55.4	2.8	1.4	10.0
190.2135	17.0	18.3	-55.4	-20.1	0.1	10.0
217.3869	43.3	16.7	-55.4	4.6	1.7	10.0
244.5603	25.4	17.0	-55.4	-13.0	0.2	10.0
271.7336	34.7	17.3	-55.4	-3.5	0.7	10.0

checked by J Stoffel

[illegible]

[illegible] : [illegible]
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 200 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1702	37.1	11.0	-55.4	-7.3	0.4	0.0
54.3418	13.5	13.0	-55.4	-28.9	0.0	10.0
81.5127	28.4	8.7	-55.4	-18.4	0.1	10.0
108.6836	28.1	11.9	-55.4	-15.5	0.2	10.0
135.8546	17.2	12.3	-55.4	-26.0	0.1	10.0
163.0255	32.0	19.4	-55.4	-4.1	0.6	10.0
190.1764	24.2	18.3	-55.4	-12.9	0.2	10.0
217.3673	38.1	16.7	-55.4	-0.6	0.9	10.0
244.5382	19.5	17.0	-55.4	-18.9	0.1	10.0
271.7091	28.6	17.3	-55.4	-9.6	0.3	10.0

Checked by: J Stoffel

[illegible]
[illegible] ELECTROMAGNETIC [illegible]
DATA [illegible]

TITLE : [illegible]
MANUFACTURER : C
MODEL # :
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 300 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1691	38.7	11.0	-55.4	-5.7	0.5	0.0
54.3383	15.3	13.0	-55.4	-27.1	0.0	10.0
81.5074	29.1	8.7	-55.4	-17.7	0.1	10.0
108.6765	29.3	11.9	-55.4	-14.3	0.2	10.0
135.8457	17.1	12.3	-55.4	-26.1	0.0	10.0
163.0148	31.6	19.4	-55.4	-4.3	0.6	10.0
190.1840	24.6	18.3	-55.4	-12.5	0.2	10.0
217.3531	42.1	16.7	-55.4	3.4	1.5	10.0
244.5222	25.3	17.0	-55.4	-13.1	0.2	10.0
271.6914	24.6	17.3	-55.4	-13.6	0.2	10.0

checked by: J Stoffel

ETR 6/82
ELITE ELECTRONIC ENGINEERING CO.
DATA SHEET

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 320 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1710	40.3	11.0	-55.4	-4.1	0.6	0.0
54.3421	16.3	13.0	-55.4	-26.1	0.0	10.0
81.5131	31.9	8.7	-55.4	-14.9	0.2	10.0
108.6842	28.6	11.9	-55.4	-15.0	0.2	10.0
135.8552	25.4	12.3	-55.4	-17.8	0.1	10.0
163.0263	41.7	19.4	-55.4	5.6	1.9	10.0
190.1973	22.0	18.3	-55.4	-15.1	0.2	10.0
217.3684	41.4	16.7	-55.4	2.7	1.4	10.0
244.5394	28.1	17.0	-55.4	-10.3	0.3	10.0
271.7104	33.5	17.3	-55.4	-4.7	0.6	10.0

checked by: J Stoffel

[illegible]
[illegible]
[illegible]

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : C
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 340 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1751	39.1	11.0	-55.4	-5.3	0.5	0.0
54.3503	16.0	13.0	-55.4	-26.4	0.0	10.0
81.5254	33.3	8.7	-55.4	-13.5	0.2	10.0
108.7005	29.1	11.9	-55.4	-14.5	0.2	10.0
135.8757	28.0	12.3	-55.4	-15.2	0.2	10.0
163.0508	43.4	19.4	-55.4	7.3	2.3	10.0
190.2259	27.9	18.3	-55.4	-9.2	0.3	10.0
217.4011	43.6	16.7	-55.4	4.9	1.8	10.0
244.5762	26.0	17.0	-55.4	-12.4	0.2	10.0
271.7513	33.5	17.3	-55.4	-4.7	0.6	10.0

checked by: J. Stoffel

GROUND RF FIELD MEASUREMENTS - MACHINE D

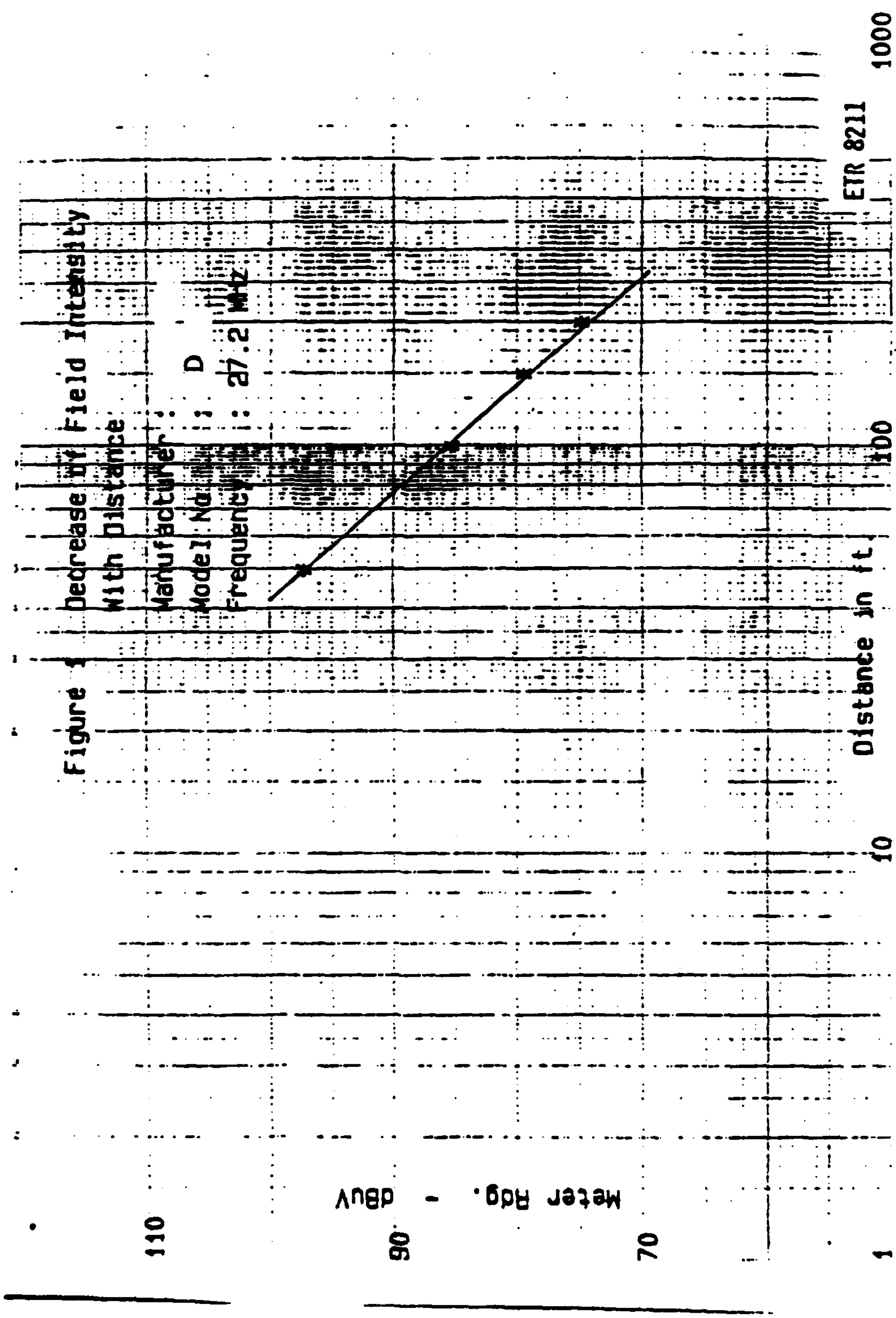


Figure B-10. Machine D Ground Determined Decay Exponent

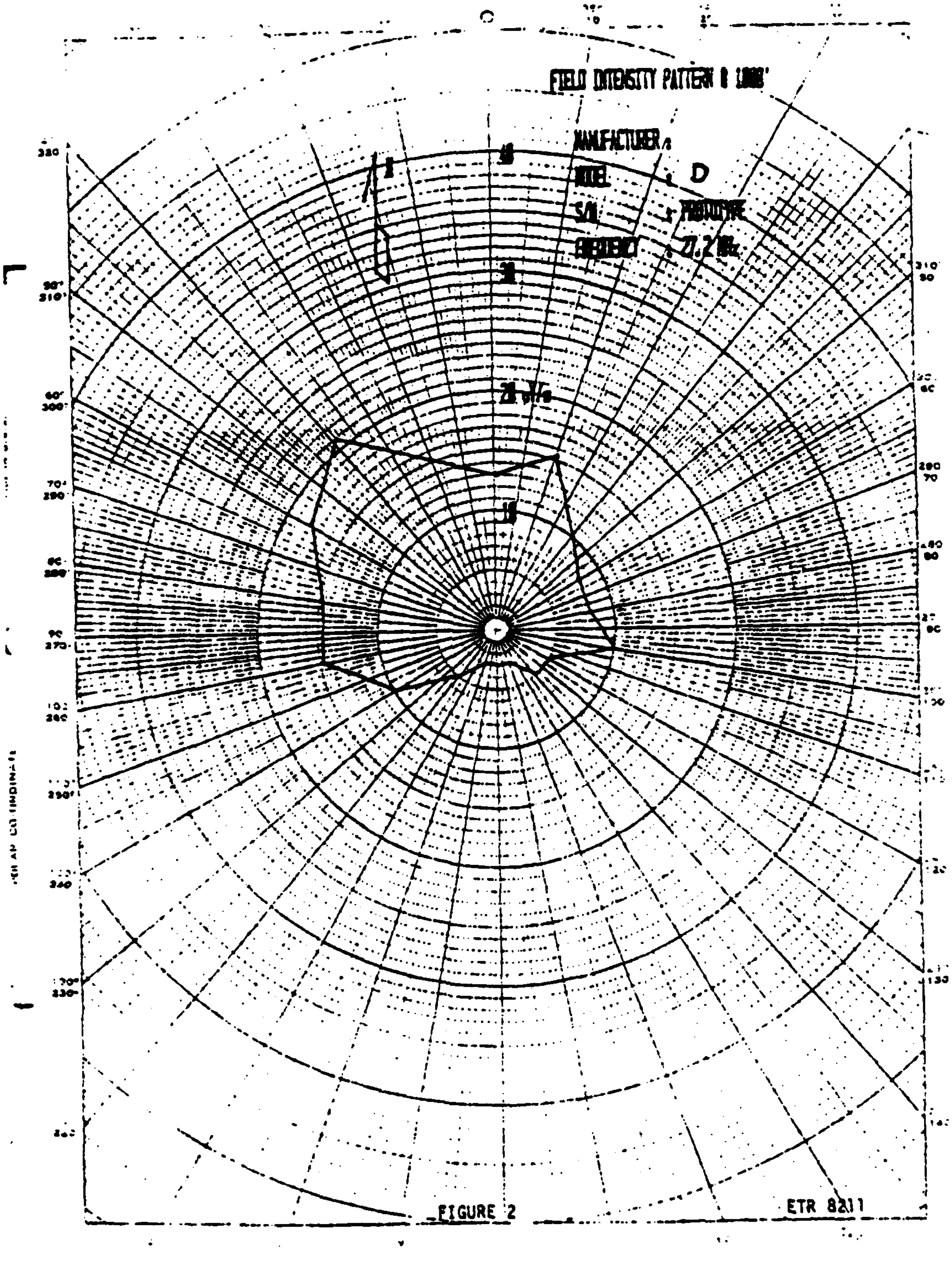


Figure B-11. Machine D Operating Frequency Field Intensity at 1000 feet

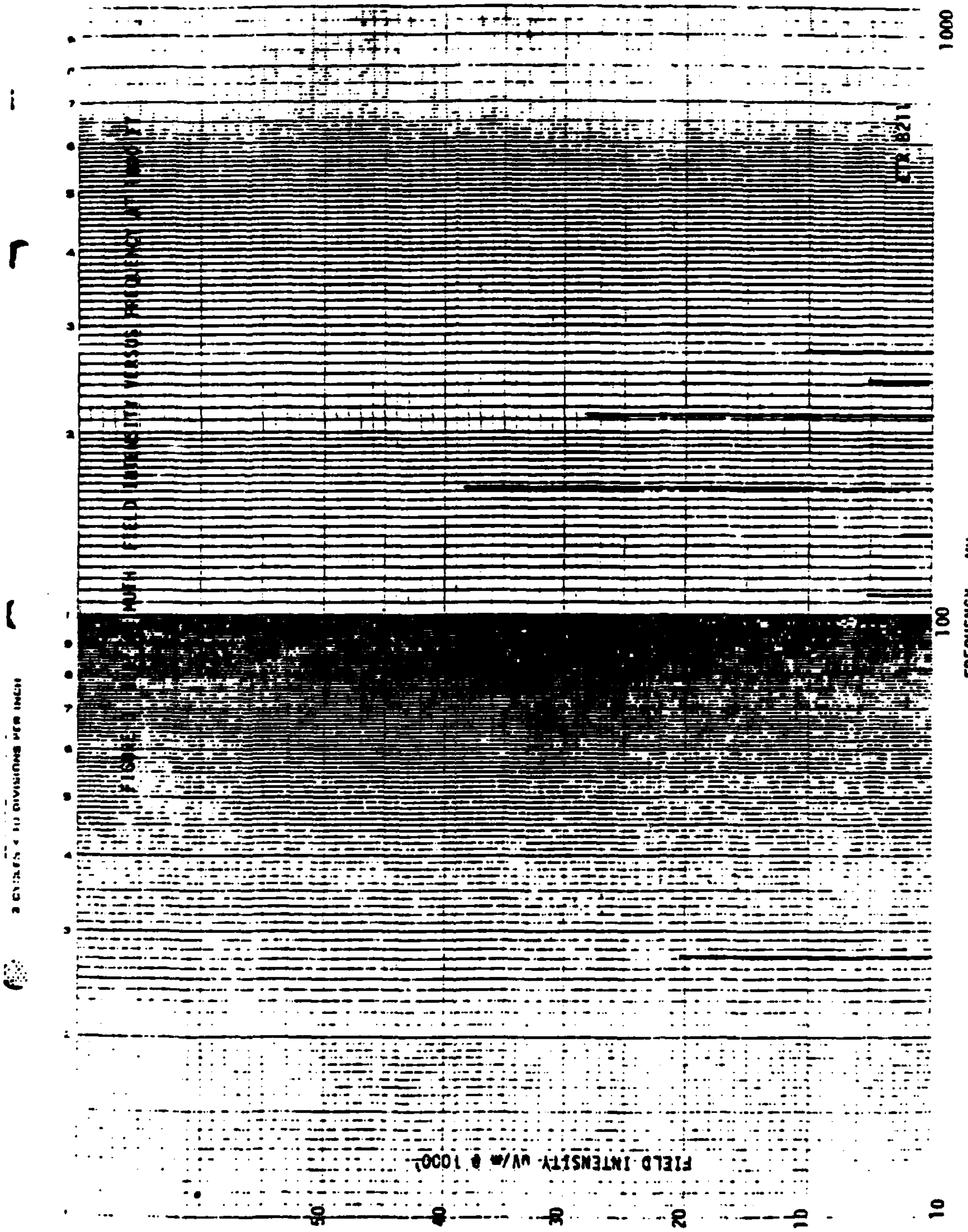


Figure B-12. Machine D Field Intensity vs. Frequency

ETR [illegible]
[illegible] ELECTRONIC ENGINEERING CO.
[illegible]

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 0 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1854	39.2	11.0	-55.4	-5.2	0.5	0.0
54.3707	14.5	13.0	-55.4	-28.0	0.0	10.0
81.5561	31.0	8.7	-55.4	-15.8	0.2	10.0
108.7414	26.7	11.9	-55.4	-16.9	0.1	10.0
135.9268	21.6	12.3	-55.4	-21.6	0.1	10.0
163.1121	41.8	19.4	-55.4	5.8	1.9	10.0
190.2975	28.0	18.3	-55.4	-9.1	0.3	10.0
217.4828	40.4	16.7	-55.4	1.7	1.2	10.0
244.6682	17.1	17.0	-55.4	-21.3	0.1	10.0
271.8535	32.6	17.3	-55.4	-5.6	0.5	10.0

checked by: J. Stoffel

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DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 20 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1863	39.7	11.0	-55.4	-4.5	0.6	0.0
54.3726	14.9	13.0	-55.4	-27.6	0.0	10.0
81.5588	29.8	8.7	-55.4	-17.0	0.1	10.0
108.7451	22.8	11.9	-55.4	-20.8	0.1	10.0
135.9314	19.7	12.3	-55.4	-23.5	0.1	10.0
163.1177	40.8	19.4	-55.4	4.8	1.7	10.0
190.3040	26.2	18.3	-55.4	-10.9	0.3	10.0
217.4902	40.5	16.7	-55.4	1.8	1.2	10.0
244.6765	21.0	17.0	-55.4	-17.4	0.1	10.0
271.8628	29.6	17.3	-55.4	-8.6	0.4	10.0

checked by: J. Stoffel

ETR 0011
ELITE ELECTRONIC ENGINEERING CO
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 40 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1743	36.1	11.0	-55.4	-8.3	0.4	0.0
54.3487	12.9	13.0	-55.4	-29.5	0.0	10.0
81.5230	30.6	8.7	-55.4	-16.2	0.2	10.0
108.6974	17.2	11.9	-55.4	-26.4	0.0	10.0
135.8717	16.9	12.3	-55.4	-26.3	0.0	10.0
163.0461	42.0	19.4	-55.4	5.9	2.0	10.0
190.2204	18.6	18.3	-55.4	-18.5	0.1	10.0
217.3948	41.8	16.7	-55.4	3.1	1.4	10.0
244.5691	25.9	17.0	-55.4	-12.5	0.2	10.0
271.7435	26.4	17.3	-55.4	-11.8	0.3	10.0

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[illegible]
[illegible] ELECTRONIC ENGINEERING [illegible]
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL [illegible] EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 60 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1771	34.4	11.0	-55.4	-10.0	0.3	0.0
54.3542	14.9	13.0	-55.4	-27.5	0.0	10.0
81.5314	24.3	8.7	-55.4	-22.5	0.1	10.0
108.7085	20.3	11.9	-55.4	-23.3	0.1	10.0
135.8856	21.4	12.3	-55.4	-21.8	0.1	10.0
163.0627	37.5	19.4	-55.4	1.4	1.2	10.0
190.2398	20.1	18.3	-55.4	-17.0	0.1	10.0
217.4169	38.1	16.7	-55.4	-0.6	0.9	10.0
244.5941	19.9	17.0	-55.4	-18.5	0.1	10.0
271.7712	29.1	17.3	-55.4	-9.1	0.4	10.0

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FTR [illegible]
[illegible] ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 80 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1708	33.3	11.0	-55.4	-11.1	0.3	0.0
54.3417	12.0	13.0	-55.4	-30.4	0.0	10.0
81.5125	20.6	8.7	-55.4	-26.2	0.0	10.0
108.6834	21.8	11.9	-55.4	-21.8	0.1	10.0
135.8542	20.8	12.3	-55.4	-22.4	0.1	10.0
163.0251	22.3	19.4	-55.4	-13.8	0.2	10.0
190.1252	23.3	18.3	-55.4	-13.8	0.2	10.0
217.3668	39.9	16.7	-55.4	1.2	1.1	10.0
244.5376	22.0	17.0	-55.4	-16.4	0.2	10.0
271.7085	29.7	17.3	-55.4	-8.5	0.4	10.0

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ETR [illegible]
[illegible] ELECTRONIC ENGINEERING CO
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 100 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1708	36.4	11.0	-55.4	-8.0	0.4	0.0
54.3417	13.4	13.0	-55.4	-29.0	0.0	10.0
81.5125	26.8	8.7	-55.4	-20.0	0.1	10.0
108.6833	25.0	11.9	-55.4	-18.6	0.1	10.0
135.8541	26.4	12.3	-55.4	-16.8	0.1	10.0
163.0250	40.8	19.4	-55.4	4.7	1.7	10.0
190.1958	32.1	18.3	-55.4	-5.0	0.6	10.0
217.3666	39.0	16.7	-55.4	0.3	1.0	10.0
244.5374	24.2	17.0	-55.4	-14.2	0.2	10.0
271.7083	33.6	17.3	-55.4	-4.6	0.6	10.0

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... ELECTRO & ENGINEERING CO.

DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 120 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1743	31.0	11.0	-55.4	-12.6	0.2	0.0
54.3486	13.0	13.0	-55.4	-29.4	0.0	10.0
81.5229	26.7	8.7	-55.4	-20.1	0.1	10.0
108.6971	26.7	11.9	-55.4	-16.9	0.1	10.0
135.8714	24.8	12.3	-55.4	-18.4	0.1	10.0
163.0457	43.1	19.4	-55.4	7.0	2.3	10.0
190.2200	34.8	18.3	-55.4	-2.3	0.8	10.0
217.3943	41.1	16.7	-55.4	2.4	1.3	10.0
244.5686	24.1	17.0	-55.4	-14.3	0.2	10.0
271.7429	34.2	17.3	-55.4	-4.0	0.6	10.0

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ETR [illegible]
ELITE ELECTRONIC ENGINEERING CO
DATA PAGE

TEST : FCC PART 18B INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 140 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1745	30.6	11.0	-55.4	-13.8	0.2	0.0
54.3490	12.1	13.0	-55.4	-30.3	0.0	10.0
81.5234	28.4	8.7	-55.4	-18.4	0.1	10.0
108.6979	27.1	11.9	-55.4	-16.5	0.1	10.0
135.8724	29.8	12.3	-55.4	-13.4	0.2	10.0
163.0469	44.9	19.4	-55.4	8.8	2.8	10.0
190.2214	32.3	18.3	-55.4	-4.8	0.6	10.0
217.3958	41.8	16.7	-55.4	3.1	1.4	10.0
244.5703	28.0	17.0	-55.4	-10.4	0.3	10.0
271.7448	33.9	17.3	-55.4	-4.3	0.6	10.0

Checked by: J. Stoffel

ETR [illegible]
[illegible] ELECTRONIC ENGINEERING CO
DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTORER 13, 1983

Test Distance : 200 ft. Azimuth : 160 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1785	22.4	11.0	-55.4	-22.0	0.1	0.0
54.3569	13.5	13.0	-55.4	-28.9	0.0	10.0
81.5354	27.8	8.7	-55.4	-17.0	0.1	10.0
108.7139	26.7	11.9	-55.4	-16.9	0.1	10.0
135.8923	29.0	12.3	-55.4	-14.2	0.2	10.0
163.0708	42.6	19.4	-55.4	6.6	2.1	10.0
190.2493	27.6	18.3	-55.4	-7.5	0.4	10.0
217.4277	42.7	16.7	-55.4	4.0	1.6	10.0
244.6062	29.8	17.0	-55.4	-8.6	0.4	10.0
271.7847	33.5	17.3	-55.4	-4.7	0.6	10.0

checked by: J. Stoffel

ETP [illegible]
[illegible] ELECTRONIC ENGINEERING CO
DATA PAGE

[illegible] : FCC PART 18 INDUSTRIAL HEATING [illegible]
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 180 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1058	19.7	11.0	-55.4	-24.7	0.1	0.0
54.3717	12.0	13.0	-55.4	-30.5	0.0	10.0
81.5575	30.0	8.7	-55.4	-16.8	0.1	10.0
108.7434	25.3	11.9	-55.4	-18.3	0.1	10.0
135.9292	26.9	12.3	-55.4	-16.3	0.2	10.0
163.1150	43.0	19.4	-55.4	7.0	2.2	10.0
190.3009	24.8	18.3	-55.4	-12.3	0.2	10.0
217.4867	44.3	16.7	-55.4	5.6	1.9	10.0
244.6726	29.7	17.0	-55.4	-8.7	0.4	10.0
271.8584	33.5	17.3	-55.4	-4.7	0.6	10.0

checked by: J. Stoffel

[illegible]
[illegible] ELECTRONIC ENGINEERING [illegible]
DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 200 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1788	26.4	11.0	-55.4	-18.0	0.1	0.0
54.3576	13.2	13.0	-55.4	-29.2	0.0	10.0
81.5365	30.6	8.7	-55.4	-16.2	0.2	10.0
108.7153	25.7	11.9	-55.4	-17.9	0.1	10.0
135.8941	30.0	12.3	-55.4	-13.2	0.2	10.0
163.0729	38.0	19.4	-55.4	2.0	1.3	10.0
190.2518	29.2	18.3	-55.4	-7.9	0.4	10.0
217.4306	42.5	16.7	-55.4	3.8	1.5	10.0
244.6094	26.7	17.0	-55.4	-11.7	0.3	10.0
271.7882	30.4	17.3	-55.4	-7.8	0.4	10.0

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ETR 0211
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18B INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 220 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1855	31.4	11.0	-55.4	-13.0	0.2	0.0
54.3710	13.2	13.0	-55.4	-29.3	0.0	10.0
81.5566	27.1	8.7	-55.4	-17.7	0.1	10.0
108.7421	26.2	11.9	-55.4	-17.4	0.1	10.0
135.9276	29.2	12.3	-55.4	-14.0	0.2	10.0
163.1131	41.5	19.4	-55.4	5.5	1.9	10.0
190.2987	29.0	18.3	-55.4	-8.1	0.4	10.0
217.4842	36.0	16.7	-55.4	-2.7	0.7	10.0
244.6697	22.7	17.0	-55.4	-15.7	0.2	10.0
271.8552	32.6	17.3	-55.4	-5.6	0.5	10.0

checked by: J. Stoffel

[illegible]
[illegible]
[illegible]

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 240 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1831	37.3	11.0	-55.4	-7.1	0.4	0.0
54.3662	13.5	13.0	-55.4	-29.0	0.0	10.0
81.5494	27.6	8.7	-55.4	-19.2	0.1	10.0
108.7325	25.2	11.9	-55.4	-18.4	0.1	10.0
135.9156	30.2	12.3	-55.4	-13.0	0.2	10.0
163.0987	42.0	19.4	-55.4	6.0	2.0	10.0
190.2819	24.6	18.3	-55.4	-12.5	0.2	10.0
217.4650	42.4	16.7	-55.4	3.7	1.5	10.0
244.6481	20.8	17.0	-55.4	-17.6	0.1	10.0
271.8312	34.2	17.3	-55.4	-4.0	0.6	10.0

checked by: J. Stoffel

FTR [illegible]
[illegible] ELECTRONIC [illegible]
DATA PAGE

[illegible] : FCC PART 18 INDUSTRIAL [illegible] EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 260 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1817	39.7	11.0	-55.4	-4.7	0.6	0.0
54.3634	12.4	13.0	-55.4	-30.1	0.0	10.0
81.5450	26.7	8.7	-55.4	-20.1	0.1	10.0
108.7267	26.4	11.9	-55.4	-17.2	0.1	10.0
135.9084	26.7	12.3	-55.4	-16.5	0.2	10.0
163.0901	35.6	19.4	-55.4	-0.4	1.0	10.0
190.2718	18.5	18.3	-55.4	-18.6	0.1	10.0
217.4535	40.4	16.7	-55.4	1.7	1.2	10.0
244.6351	22.8	17.0	-55.4	-15.6	0.2	10.0
271.8168	33.6	17.3	-55.4	-4.6	0.6	10.0

checked by: J. Stoffel

ETR 8211
[illegible] ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18 INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 280 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1832	40.6	11.0	-55.4	-3.8	0.6	0.0
54.3665	13.2	13.0	-55.4	-29.3	0.0	10.0
81.5497	24.9	8.7	-55.4	-21.9	0.1	10.0
108.7330	28.0	11.9	-55.4	-15.6	0.2	10.0
133.9162	19.4	12.3	-55.4	-23.8	0.1	10.0
163.0995	33.0	19.4	-55.4	-3.0	0.7	10.0
190.2827	20.8	18.3	-55.4	-16.3	0.2	10.0
217.4660	34.8	16.7	-55.4	-3.9	0.6	10.0
244.6492	17.3	17.0	-55.4	-21.1	0.1	10.0
271.8325	24.1	17.3	-55.4	-14.1	0.2	10.0

checked by: J. Stoffel

[illegible]
[illegible]
[illegible]

TEST : FCC PART [illegible]
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 300 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1872	41.5	11.0	-55.4	-2.9	0.7	0.0
54.3744	13.5	13.0	-55.4	-29.0	0.0	10.0
81.5615	24.6	8.7	-55.4	-22.2	0.1	10.0
108.7487	27.5	11.9	-55.4	-16.1	0.2	10.0
135.9359	18.1	12.3	-55.4	-25.1	0.1	10.0
163.1231	33.6	19.4	-55.4	-2.4	0.8	10.0
170.3102	21.8	18.3	-55.4	-15.3	0.2	10.0
217.4974	39.0	16.7	-55.4	0.3	1.0	10.0
244.6846	22.4	17.0	-55.4	-16.0	0.2	10.0
271.8718	29.2	17.3	-55.4	-9.0	0.4	10.0

checked by: J. Stoffel

[illegible]
[illegible] ELECTRONIC ENGINEERING CO.
[illegible]

TEST : FCC PART 18 INDUCTION HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 Ft. Azimuth : 320 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1905	42.9	11.0	-55.4	-1.5	0.8	0.0
54.3810	15.1	13.0	-55.4	-27.4	0.0	10.0
81.5716	28.6	8.7	-55.4	-18.2	0.1	10.0
108.7621	29.1	11.9	-55.4	-14.5	0.2	10.0
135.9526	21.2	12.3	-55.4	-22.0	0.1	10.0
163.1431	39.7	19.4	-55.4	3.7	1.5	10.0
190.3336	22.1	18.3	-55.4	-15.1	0.2	10.0
217.5242	39.8	16.7	-55.4	1.1	1.1	10.0
244.7147	25.8	17.0	-55.4	-12.6	0.2	10.0
271.9052	31.1	17.3	-55.4	-7.1	0.4	10.0

checked by: J. Stoffel

ETR 87-11
ELITE ELECTRONIC ENGINEERING CO.
DATA PAGE

TEST : FCC PART 18D INDUSTRIAL HEATING EQUIPMENT
MANUFACTURER :
MODEL # : D
S/N : PROTOTYPE
DATE TESTED : OCTOBER 13, 1983

Test Distance : 200 ft. Azimuth : 340 degrees
Corrections based on a field decay exponent of 1.95

Freq. MHz	Mtr Rdg dBuV	Ant. fac. dB	Dist. corr dB	Total dBuV/m @ 1mile	Total uV/m @ 1mile	Limit uV/m @ 1mile
27.1896	37.8	11.0	-55.4	-4.6	0.6	0.0
54.3792	14.5	13.0	-55.4	-28.0	0.0	10.0
81.5689	29.5	8.7	-55.4	-17.3	0.1	10.0
108.7585	28.3	11.9	-55.4	-15.3	0.2	10.0
135.9481	23.2	12.3	-55.4	-20.0	0.1	10.0
163.1377	43.2	19.4	-55.4	7.2	2.3	10.0
190.3273	27.1	18.3	-55.4	-10.1	0.3	10.0
217.5169	40.0	16.7	-55.4	1.3	1.2	10.0
244.7066	24.2	17.0	-55.4	-14.2	0.2	10.0
271.8962	33.1	17.3	-55.4	-5.1	0.6	10.0

checked by: J. Stoffel

Appendix C.

Details of the calibration of an EMCO 3104 biconical antenna are reported. Calibration data for this antenna at 27 MHz and 109 MHz are given.

TECHNICAL MEMORANDUM Y-1

BICONICAL ANTENNA CALIBRATION - THREE ANTENNA METHOD

Details of the calibration of an EMCO 3104 biconical antenna are reported. Calibration data for this antenna at 27 MHz and 109 MHz are given.

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April 1984

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Federal Aviation Administration
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Contract No: DTFA01-83-C-10007

TABLE OF CONTENTS

I. PURPOSE

To calibrate a biconical antenna at 27 and 109 MHZ so that the antenna may be used to transmit a calibrated RF field or measure an unknown RF field. This procedure yields the absolute gain over an isotropic source for an antenna, which can be used to determine an antenna factor to use for measuring purposes.

II. THEORY OF OPERATION

This calibration procedure is based on the material presented in [1] and is summarized below.

The absolute gain of an antenna over an isotropic source can be determined if there are three relatively similar antennas (that is three antennas with similar radiating patterns). This method is based on the relation of the product of two antenna gains to the received and transmitted power given by equation 1 when the two antennas are set up so that one is transmitting to the other.[2]

$$G = \sqrt{G_{01}G_{02}} = \frac{4\pi s}{\lambda}\sqrt{\frac{Wr}{Wt}} \qquad \text{(eq. 1)}$$

where G_{01} is the gain of antenna 1

G_{02} is the gain of antenna 2

S is the spacing between the two antennas

λ is the wavelength

W_r is the received power, and

W_t is the transmitted power

If three antennas are used then there are three possible combinations of two antennas and three gain measurements. From these three measured product gains the gain of each antenna can be calculated as follows:

If the test configurations are

	Transmit	Receive
no. 1	Ant. 1	Ant. 3
no. 2	Ant. 2	Ant. 3
no. 3	Ant. 2	Ant. 1

and

G_{0n} = isotropic gain of antenna n

G_n = gain of nth test configuration

W_{rn} = received power of nth configuration

W_{tn} = transmitted power of nth configuration

then

$$G_1 = \sqrt{G_{01}G_{03}} = \frac{4\pi S_1}{\lambda_1}\sqrt{\frac{W_{r1}}{W_{t1}}} \qquad \text{(A)}$$

$$G_2 = \sqrt{G_{02}G_{03}} = \frac{4\pi S_2}{\lambda_2}\sqrt{\frac{W_{r2}}{W_{t2}}} \qquad \text{(B)}$$

$$C_3 = \sqrt{G_{02}G_{01}} = \frac{4\pi S_3}{\lambda_3} \sqrt{\frac{W_{r3}}{W_{t3}}} \qquad \text{(C)}$$

By assuming that S1=S2=S3=S and $\lambda_1=\lambda_2=\lambda_3=\lambda$ which can be achieved by using identical test configurations.

$$\text{from (A)} \quad G_{01}G_{03} = \left(\frac{4\pi S}{\lambda}\right)^2 \frac{W_{r1}}{W_{t1}} \rightarrow G_{03} = \left(\frac{4\pi S}{\lambda}\right)^2 \frac{W_{r1}}{W_{t1}} \frac{1}{G_{01}} \qquad \text{(A1)}$$

$$\text{from (B)} \quad G_{02}G_{03} = \left(\frac{4\pi S}{\lambda}\right)^2 \frac{W_{r2}}{W_{t2}} \rightarrow G_{03} = \left(\frac{4\pi S}{\lambda}\right)^2 \frac{W_{r2}}{W_{t2}} \frac{1}{G_{02}} \qquad \text{(B1)}$$

equating (A1) and (B1) gives

$$G_{02} = \frac{W_{t1}W_{r2}}{W_{r1}W_{t2}} G_{01} \qquad \text{(D)}$$

substituting (D) into (C) yields

$$G_{01} = \frac{4\pi S}{\lambda} \sqrt{\frac{W_{r1}W_{t2}W_{r3}}{W_{t1}W_{r2}W_{t3}}} \qquad \text{(E)}$$

substituting (E) into (D) yields

$$G_{02} = \frac{4\pi S}{\lambda} \sqrt{\frac{W_{t1}W_{r2}W_{r3}}{W_{r1}W_{t2}W_{t3}}} \qquad \text{(F)}$$

and substituting (F) into (B1) gives

$$G_{03} = \frac{4\pi S}{\lambda} \sqrt{\frac{W_{r1}W_{r2}W_{t3}}{W_{t1}W_{t2}W_{r3}}} \qquad \text{(G)}$$

Thus, (E), (F), and (G) are expressions for the absolute gains of antennas 1,2, and 3 respectively.

The conversion to antenna factor from power ratio gain in dB can then be calculated using equation 2. This antenna factor is then added to a voltmeter reading to obtain the absolute signal strength in dBuV/m.

$$K = 20\log(f) - G - 29.8 \qquad \text{(eq. 2)}$$
$$\text{for } Z = 50 \text{ ohm}$$

where K= antenna factor in dBuV/m

f= frequency in MHZ

G= antenna power ratio gain in dB

III. EQUIPMENT

Antennas
- Biconical antenna, EMCO model 3104, O.U. no. 1484
- Dipole antenna CU-683/URM-7, O.U. no. 0370
- Dipole antenna marked 'EMI REFERENCE'
- 11 antenna elements AB-21/GR
- 2 antenna elements AT-848/URM-7
- 2 aluminum antenna elements 40 inches long

Signal generator
- Wavetek 3000 - O.U. no. 1298
- Avantek RF power amplifier

Detection units
- EMC-25 Selective voltmeter
- HP141T Spectrum analyzer

Directional Coupler
- HP778D Dual Directional coupler serial no. 1144A04704

Antenna towers
- Clark tower - max. height approx. 70 feet
- Tripod stand MT-1947/URM-7 - max. height 15 feet
- Tripod stand TRP-25, O.U. no. 1483

Cables - all cables to be 50 ohm coaxial
- EMI cable A (approximately 35 feet long)
- EMI cable B (approximately 80 feet long)
- Several short interconnect cables

DC power supply
- HP 6237B triple output

AC power source
- gas powered alternator
- 100 ft. extension cord
- multiple outlet extension cord

Connectors for all setups

IV. SETUP

The entire test setup is to be located in a place that is as free from RF noise as possible and clear of any large metallic objects that may in any way alter the propagation of the transmitted signal. It is suggested that any large metallic objects in the test area be at a distance from either antenna equal to not less than three times the spacing between the two antennas. Also the area chosen should be as flat as possible and the surface should be of approximately the same material throughout the test area.

The two antennas are to be separated by a distance such that the receiving antenna is in the 'far field' of the transmitted signal. This distance is to be a minimum of three times the wavelength.[3] In addition, the two antennas are to be oriented for maximum coupling and placed on towers at heights such that the summation of the direct wave and the ground reflected wave is a maximum.

The height requirement of the antenna setup is that the two antennas be at heights that cause the ground reflected wave present at the receiving antenna to be in phase with the direct wave, so that a maximum signal is received. The height requirement is due to the fact that near the point of maximum combined signals the variation in signal strength with height is at a minimum, thus giving a more uniform field. Although the point where the antenna must be placed has to be determined by moving the antenna vertically and watching the received signal for a maximum, a simplified formula that gives antenna height h_2 in terms of antenna height h_1, spacing S, and the wavelength is given in equation 3.[4]

$$h_2 = n\frac{\lambda}{4} \times \frac{S}{h_1} \qquad \text{(eq.3)}$$

with $n = 0,2,4,\ldots$ for minimums and
$n = 1,3,5,\ldots$ for maximums
providing $S \gg h_1$ or h_2

The signal generator Avantek amplifier combination is used as the source for the transmitting antenna and the HP141T spectrum analyzer is used to measure the received signal. The output of the RF amplifier is fed to the transmitting antenna through the dual directional coupler. The dual directional coupler is used so that the forward and reflected power to the transmitting antenna can be measured with the EMC-25 receiver. The transmitted power is then calculated by subtracting the reflected power from the forward power. Note that the cable attenuation must be considered when performing the measurements of forward, reflected, and received power. Also note that the value of the transmitting antenna cable attenuation is subtracted from the measured forward power and is added to the measured reflected power.

V. PROCEDURES

1. Set up the equipment as described in the SETUP section with the DC power supply providing power to the Avantek RF power amplifier. Turn on all the equipment and adjust the controls so that a signal at least 20 dB above the noise level can be detected at the receiving end. Note that a load should be applied to the RF power amp before DC power is applied.

2. Adjust one or both antennas in altitude and/or orientation so that a maximum signal level of sufficient amplitude (>20 dB above noise) is detected at the receiver.

3. Record the forward, reflected, and received power. Also record the frequency setting, height of both antennas, and the spacing between antennas along with the description of the two antennas used.

4. Exchange the transmitting antenna with the antenna previously unused, keeping the height and spacing of the antennas the same (remember to turn off power to the RF power amp before disconnecting the transmitting antenna). Turn the power amp back on when the antenna is in place and adjust the signal generator setting, if necessary, to obtain proper received signal.

5. Record the information listed in part 3 for this antenna configuration.

6. Obtain the measurements for the final configuration by exchanging the receiving antenna with the antenna first used as the transmitting antenna and repeating the procedures above.

7. Compute the gain of the antennas using the formulas presented and the transmitted and received power just measured. Remember that the transmitted power is equal to the forward power minus the reflected power (do not forget to convert from dBm to watts before subtracting).

VI. EXAMPLE

This section describes in detail the test setup used on September 9,1983 and the results obtained by Jim Nickum, Bill Drury, and Dave Quinet. Antenna numbers given are referenced to the configurations in the 'THEORY OF OPERATION' section.

<u>109 MHZ</u>

<u>Antenna</u> 1: Dipole antenna CU-683/URM-7 with AT-848/URM-7 element each side extended for antenna length equal to 1/2 wavelength at 109 MHZ.

Antenna 2: Dipole antenna 'EMI REFERENCE' with AB-21/GR element each side.

Antenna 3: Biconical antenna EMCO 3104

Separation distance: 41 feet

Receiving antenna height: 6 feet

Transmitting antenna height: 13 feet

P_{fwd1} = -9.2 dBm = 120.2 E-3 mW

P_{rfl1} = -15.8 dBm = 26.3 E-3 mW

$W_{t1} = P_{fwd1} - P_{rfl1}$ = 93.9 E-3 mW = -10.3 dBm

W_{r1} = -44.2 dBm

P_{fwd2} = -9.2 dBm = 120.2 E-3 mW

P_{rfl2} = -15.8 dBm = 26.3 E-3 mW

W_{t2} = -10.3 dBm

W_{r2} = -45.2 dBm

P_{fwd3} = -9.2 dBm = 120.2 E-3 mW

P_{rfl3} = -15.8 dBm = 26.3 E-3 mW

W_{t3} = -10.3 dBm

W_{r3} = -39.7 dBm

G_{01} = 2.17

G_{02} = 1.72

G_{03} = Biconical gain = 0.61

Biconical antenna factor = 13.1 dB

27 MHZ

Antenna 1: Dipole antenna CU-683/URM-7 with 4 AB-21/GR elements plus AT-848/URM-7 elements each side extended to 1/2 wavelength at 27 MHZ.

Antenna 2: Dipole antenna marked 'EMI REFERENCE' with three AB-21/GR elements plus aluminum extensions each side. Length equal to 1/2 wavelength at 27 MHz.

Antenna 3: Biconical antenna EMCO 3104

Separation distance: 100 feet

Receiving antenna height: 63 feet

Transmitting antenna height: 13 feet

P_{fwd1} = -7.8 dBm = 166 E-3 mW

P_{rfl1} = -19.0 dBm = 12.59 E-3 mW

W_{t1} = -8.14 dBm

W_{r1} = -53.5 dBm

P_{fwd2} = -7.8 dBm = 166 E-3 mW

P_{rfl2} = -17.8 dBm = 16.6 E-3 mW

W_{t2} = -8.25 dBm

W_{r2} = -54.0 dBm

P_{fwd3} = -7.8 dBm = 166 E-3 mW

P_{rfl3} = -17.8 dBm = 16.6 E-3 mW

W_{t3} = -8.25 dBm

W_{r3} = -33.5 dBm

G_{01} = 1.96

G_{02} = 1.79

G_{03} = Gain of Biconical = 0.017

Biconical antenna factor = 16.4 dB

VII. REFERENCES

[1] Kraus, John D., 'Antennas', McGraw-Hill Book Company, New York, 1950, pp. 448-457.

[2] Ibid., p. 456.

[3] "Calibration Principles and Procedures for Field Strength Meters (30 Hz to 1 GHz)", National Bureau of Standards Technical Note 370, March 1969, p.105.

[4] "The ARRL Antenna Book", American Radio Relay League, Inc., Newington, Connecticut, 1974, p. 318.

VIII. ACKNOWLEDGEMENTS

Support and funding for this study is provided under the Federal Aviation Administration contract number DTFA01-83-10007.

Dr. Richard H. McFarland, director of the Avionics Engineering Center, served as Project Director, and Mr. James D. Nickum as Project Engineer.

END

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